DO RISK PREFERENCES INFLUENCE THE DECISION TO ADOPT NEW TECHNOLOGIES?

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ABSTRACT

This study is set in rural Colombia where potato farmers face an ongoing struggle against the Guatemalan Potato Moth. In 2009, a new technology was devised that was both environmentally friendly and efficient at neutralizing this pest. The present paper seeks to identify the main factors that affect the probability of farmers adopting this type of technology. More specifically, it assesses whether farmers' risk preferences influence their willingness to adopt a new technology. It also gauges the extent to which they will adopt. We find that the main barriers to adoption are the characteristics of the new technologies themselves. Furthermore, while farmers' risk preferences do not impact their decision to adopt a new technology, they do influence the extent to which they will adopt.

BIOGRAPHICAL SKETCH

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Section I: Introduction

I. Motivation

Many of the world's poor rely heavily on agriculture as their main source of revenue. While this can be a lucrative business for some, the majority of smallholder farmers throughout the developing world can rarely cover their households' expenses. Indeed, they face a complex set of challenges, which include difficult and variable weather conditions, limited access to credit, and price volatility among others. Furthermore, smallholder farmers are often constrained to use outdated technologies because they lack the necessary knowledge and capital to invest in superior techniques. In the last few decades there has been a surge in technological innovations that are specifically designed to help smallholder farmers. As a result, technological innovation is helping to increase farm productivity, thereby fuelling economic growth. The most efficient technologies are able to increase output while protecting the environment and safeguarding human health.

These new technologies present many clear benefits to farmers, and yet adoption rates consistently remain low. Many studies have investigated the reasons behind this (Barrett and Moser, 2006; Besley and Case, 1994; Conley and Udry, 2010; Croppenstedt, Demeke and Meschi, 2003; Foster and Rosenzweig, 1995; Munshi, 2004; Liu, 2012). They successfully establish that low levels of education, credit constraints, insufficient capital and lack of information prevent farmers from testing the efficiency of new technologies. Recently, a growing number of papers have identified two new barriers to adoption: farmers' risk preferences and their interactions with their social network (Liu, 2012; Conley and Udry, 2010). These studies make use complex survey instruments in order to properly identify the impact of risk and social networks on the decision to adopt. In order to precisely estimate a farmer's preference for risk, researchers must make use of experimental games. In these games, farmers are asked to choose between various different lotteries. Some of these lotteries are inherently riskier than others:

they yield higher payoffs with less certainty. Based on the choices they make in the game, farmers are then assigned a precise measure of risk aversion.

The purpose of this paper is to gain a better understanding of how farmers' risk preferences affect their decision to adopt a new technology. We also hope to determine whether risk preferences impact the extent to which farmers adopt. Most studies measure "extent of adoption" by recording the number of acres farmers choose to devote to the new technology, given their decision to adopt.

II. Purpose of the Study

The current paper is set in rural Colombia where farmers face an ongoing struggle against an aggressive pest known as the Guatemalan potato moth (*Tecia Solanivora)*. This insect has wiped out entire harvests and continuously threatens farmers' livelihood. In 2009 entomologists from Cornell University, began developing a new technology that presents a number of clear benefits to the farmers: it protects their crop yields from the potato moth while reducing crop exposure to harmful pesticides (Poveda and Gómez, 2009). More specifically, this push pull technology combines the use of a garlic pepper extract to repel the moths, and rows of trap plants to attract and neutralize the pest.

The current study's main goal is to identify which factors will encourage or impede farmers' adoption of similarly innovative technologies. More specifically, it attempts to further examine whether risk preferences will impact the decision to adopt. As a result, this study contributes broadly to the literature on technology adoption, and more specifically to the growing body of work that focuses on the role of risk preferences in adoption decisions.

There are two possible methodologies that could have been used to identify the potential barriers to adoption, including risk. The first method follows the majority of existing papers on technology adoption and employs an *ex-post* approach. Data is collected after the diffusion of the new technology takes place in order to identify the main factors that impeded adoption. While this approach provides interesting economic results, follow up is then required to address these issues if the technology is to reap its intended benefits. This step is rarely completed. From a policy perspective this is disappointing because time and resources are spent on diffusion and yet adoption rates remain low. According to Barrett and Moser (2006): “for most policymakers and development practitioners wishing to gain insights into the adoption process, *ex post* conclusions are probably not very useful”.

The second method has only been used in a handful of cases and adopts an *ex-ante* approach. Indeed it identifies the specific factors that have a high probability of the impeding the decision to adoption *before* diffusion takes place. This approach requires a measure of farmer’s *willingness* to adopt a new technology, because the researcher cannot observe whether the farmer has adopted it or not (as the technology is not yet readily available). Furthermore data needs to be collected on potential barriers to adoption. This includes farmers’ social demographics (wealth, education, age), and their risk preferences, among others. This information is then used to statistically predict which factors are most likely to increase/reduce the *probability* that the farmer adopts the new technology in the future. The findings can then be shared with the scientists that are developing the new technology, and the implementing partners that would like to diffuse the product. The former can use this information to alter certain features of the new technology and tailor it to the needs of the local farmers. The latter relies on this information to address social factors such as wealth, education or risk that might prevent farmers from adopting when diffusion actually takes place.

This paper uses the second approach for two reasons. Firstly, the entomologists from Cornell University that had developed the new technology were still in the process of running their final tests, and they were interested in knowing whether or not it would be feasible to implement it among local farmers. The answer to this question required a more in depth understanding of the farmers’ needs and preferences. The scientists could then use this information to adapt the technology accordingly. Secondly, we established that our implementing partners and government agencies could be more efficient and secure higher adoption rates if they were able to identify farmers’ main concerns and limitations beforehand. These could then be effectively addressed before diffusion takes place.

This paper is the first to use this *ex-ante* approach to specifically analyze the impact of risk preferences on the decision to adopt, and the extent to which farmers adopt. The model we select (to be detailed below) explicitly identifies farmers risk preferences as one *potential* barrier to adoption, among others. The data we collect then allows us to test whether or not risk constitutes a *real* barrier to adoption, and isolate which other factors will encourage/impede the decision to adopt.

III. Process

To this end, we led a two-month field experiment in the summer of 2012 to survey one hundred and sixty Colombian farmers in the Department of Cundinamarca (Colombia's equivalent to a State or Province). We partnered with the National Potato Growers' Federation (FEDEPAPA by its Spanish acronym) whose support was invaluable throughout the data collection process. In order to answer the main research questions we needed to characterize each farmer's willingness to adopt the technology and the extent to which they would adopt it. It was also imperative to collect information on the potential barriers of adoption.

We classify the barriers of adoption into two main groups: attributes of the new technology and attributes of the farmer. Firstly, farmers base their decision to adopt on the characteristics of the new technology. Indeed if they feel the cost is too high or the amount of labor they need to supply is excessive, they may choose not to try the new technique. Secondly, farmers' personal attributes (social factors) might influence their decision to adopt. These factors include a farmers' level of education, their wealth, their preference for risk and more. Some of these variables were much easier to collect than others. Indeed an entire experimental game had to be designed in order to obtain a measure of risk preferences.

We first define a measure for farmers' willingness to adopt. We decide to rely mainly on a choice experiment (CE), which asks farmers to choose between the status quo technology they currently use and a hypothetical alternative that differs with respect to cost, yield, labor and environmental impact. We determine that farmers who switch to the new hypothetical technology have a higher willingness to adopt. Different versions of this hypothetical technology are presented to each farmer in order to assess how they react to variations in the attributes (cost, yield, labor, environmental protection).

We select the CE methodology for two reasons. Firstly, the technology developed by Poveda and Gómez (2009) was still in the process of being tested at the time of the survey. As a result we deemed it more appropriate to measure farmers' attitudes towards a range of hypothetical technologies that differ based on certain attributes. Secondly, and most importantly, the CE *simultaneously* provides a measure of willingness to adopt, and identifies potential barriers to adoption by teasing out farmers' attitudes towards different attributes of the new technology.

We then design a contingent valuation question (CV), in order to obtain our measure for "extent of adoption". The CV asks farmers if they would be willing to rent out a small parcel of their land to scientists at Cornell University. We carefully explain to farmers that these scientists are in the process of developing a new, pesticide free technology, that will prevent the Guatemalan Potato moth from damaging their crops. Those who agree to rent their land are then asked *how much* land they would be willing to rent at the chosen price. We argue that the amount of land farmers are willing to rent to the Cornell scientists can be used as a proxy for the amount of land they would be willing to devote to the new technology should it become available. This becomes our measure for "extent of adoption".

Finally we needed to collect information on farmers' personal characteristics, as they constitute the second potential barrier to adoption. We achieve this through the use of a questionnaire and an experimental game. On the one hand, the questionnaire asks farmers about their farming practices and various household characteristics. On the other hand, an experimental game, which borrows its design from Tanaka, Nguyen and Camerer (2010), is used to measure farmers' individual risk preferences. This game presents farmers with a series of pairwise lottery choices and asks them to select their preferred lottery. We choose this game for a number of reasons. Firstly, the game has several desirable properties. Indeed it encourages farmers to answer truthfully because large winnings are at stake. The game is also relatively easy to understand given farmers level of education. Secondly the game is grounded in prospect theory, which is particularly well suited to understanding farmers' attitudes towards new technologies. More specifically, prospect theory accounts for *status quo bias*, which is likely to explain certain farmers' behavior. Indeed, some farmers will maintain the status quo rather than switch to something new. This is because they perceive the potential losses from switching to be larger than the potential gains. Kahneman and Tversky (1979) explain that this cognitive bias stems from individuals' extreme aversion to losses: individuals work harder to avoid losses than to achieve gains.

There are very few papers that use prospect theory in order to calculate subjects' risk preferences. We are one of the first to derive this measure for risk and then test whether or not it influences the decision to adopt a new technology and the extent to which farmers are willing to adopt it.

IV. Model

We develop a random utility model in order to determine the primary factors that influence the decision to adopt a new technology. In this model farmers are faced with a choice between two technologies. One represents the status quo and the other is an alternative that differs based on cost, labor requirements, yield and health/environmental impact. Farmers derive a specific level of utility from each of the two technologies, and will choose the one that provides the highest level of utility. The utility they receive from each technology depends on two independent factors: their personal characteristics, including risk preferences, and the features of the technologies themselves. Furthermore we use a reduced form equation to estimate the extent to which farmers are willing to adopt a new technique. This econometric approach is based on previous literature that has focused on similar questions (Cooper and Keim, 1996; Cooper, 1997; de Janvry and Qaim, 2003; Hubbell et al., 2000).

Our main hypothesis is that the features of the new technology will influence farmers' decision to adopt, while farmers' personal characteristics will influence the extent to which they adopt. This hypothesis was formulated after we identified the sample of farmers we would be working with. Indeed our sample consists of Colombian farmers who are affiliated with FEDEPAPA. These farmers consult agronomists on a regular basis and are frequently exposed to new products that can benefit their crops. As a result, they are in the habit of weighing a product's pros and cons before they chose to try it or not. It is likely that they will do the same when confronted with new technologies. Therefore we suspect that farmers place a lot of emphasis on the features of the new technologies when deciding whether or not to adopt. Furthermore our sample of farmers has self-selected into this association, which means they already place value on being part of a group that promotes best practices in potato farming. As a result we expect that personal characteristics, and particularly their risk preferences, may not be a driving force in the adoption decision. Conversely, we believe that these personal characteristics, and most importantly risk preferences, will influence farmers' decision to invest more or less of their own assets into the new technology. In other words, farmers' individual attributes, and their tolerance for risk, affect the *extent* to which farmers will adopt rather than the decision to adopt.

Our results confirm these hypotheses. Indeed farmers seem to base their decision to adopt solely on the features of the new technology. Moreover, the decision to invest more or less heavily in a new technique depends on farmers' personal characteristics, including their preference for risk.

V. Structure of the Thesis

The rest of the paper is structured as follows. Section II provides further motivation for the project. It reviews the main challenges facing potato growers in Colombia, and illustrates the need for new technologies. The section concludes with a summary of one such technology currently being developed by Cornell University. Understanding what would motivate a Colombian farmer to adopt this type of technology was the primary reason for this study. Section III provides an extensive review of the four different bodies of literature that we used for this study: stated preference methods, technology adoption, experimental games, and the impact of risk preferences on technology adoption. Section IV provides an in depth explanation of the data collection process and the survey design. Section V presents the econometric model and Section VI reviews the results. Section VII concludes and provides some suggestions for future research.

Section II: Background

I. Colombia Potato Farmers and Their Struggles

Potato farming represents an important sector of economic activity in Colombia. According to the Food and Agriculture Organization (FAO), Colombia produced approximately 2 million tons of potatoes in 2010 (FAO, 2010). This generated over 306 million dollars, making it the sixth most lucrative crop for the country. Millions of individual Colombians benefit directly from the industry. Indeed, there are close to 90,000 families that cultivate potatoes and thousands more daily laborers that help tend to the land (FEDEPAPA, 2007). The majority of potato growers operate small farms (0-3 hectares), which are characterized by intensive production per unit of land (Intentional Food and Policy Research Institute IFPRI, 2006). These farmers generally use high doses of chemicals and have very little access to high tech machinery (Ministerio de Agricultura y Desarrollo Rural MADR, 2005).

Potatoes are cultivated primarily in four of Colombia's thirty-two departments: Cundinamarca, Boyacá, Nariño and Antioquia (Figure 1). In 2011 approximately 131 thousand hectares were planted with potato seeds. This represents close to 16% of Colombia's arable land devoted to permanent crops (Departamento Administrativo Nacional de Estadística DANE, 2011). Potatoes need to be grown in cold climates, and the majority of farms are located in the highlands and mountainous regions approximately 2,000 to 3,500 meters above sea level (FEDEPAPA, 2005). There are usually two harvest periods each year, running from January to March and June to September (MADR, 2005).

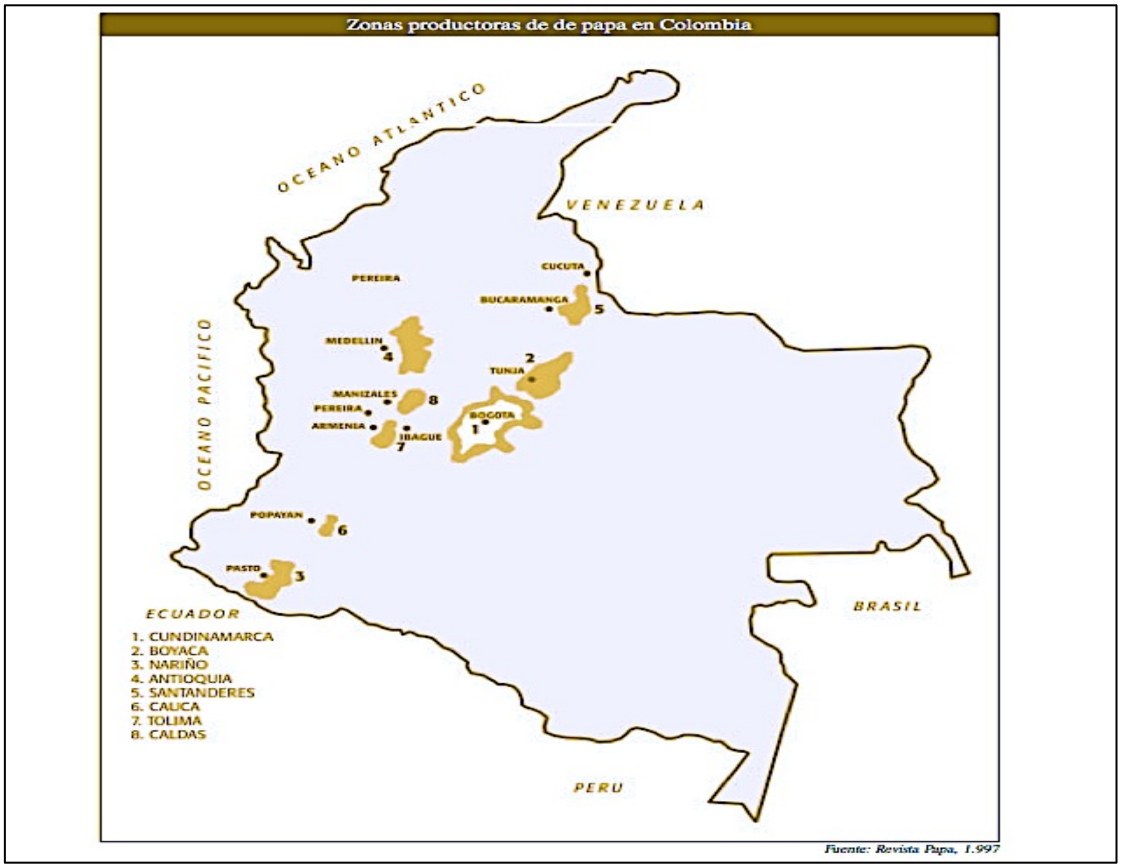

Figure 1. Map of Potato Growing Regions in Colombia[1]

Potato farmers face a growing number of challenges, which include: increases in production costs, volatility in selling prices and difficult weather conditions (particularly heavy rains and frost). The following two graphs provide concrete evidence of these economic hardships. Figure 2 depicts the growing production costs for farmers for three different types of potatoes: Pastusa Suprema, Criolla, and D. Capiro. Indeed, potato farming requires large expenditures for fertilizer, insecticides, seed and daily laborers.

[1] *Source: FEDEPAPA. Guia Ambiental Para el Cultivo de la Papa. 2005*

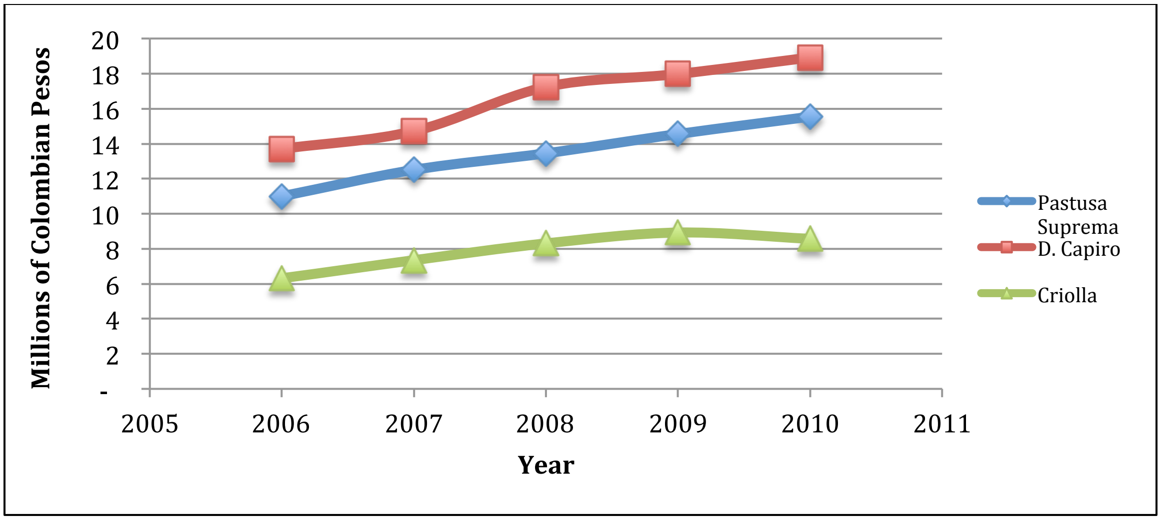

Figure 2. Total Costs of Potato Production for Three Different Varieties per Hectare, per Farmer[2]

Meanwhile farmers are also concerned about an increasingly volatile selling price for their potatoes. Figure 3 depicts this trend for one of the more popular potato varieties in Colombia: la Criolla. From one month to the next the price of the potato can rise or drop dramatically. This trend has persisted for the last 5 years (2007-2012). This makes it particularly difficult for the farmers to predict whether or not they will be able to cover their costs.

[2] *Source: FEDEPAPA. Annual Review of Costs. 2012*

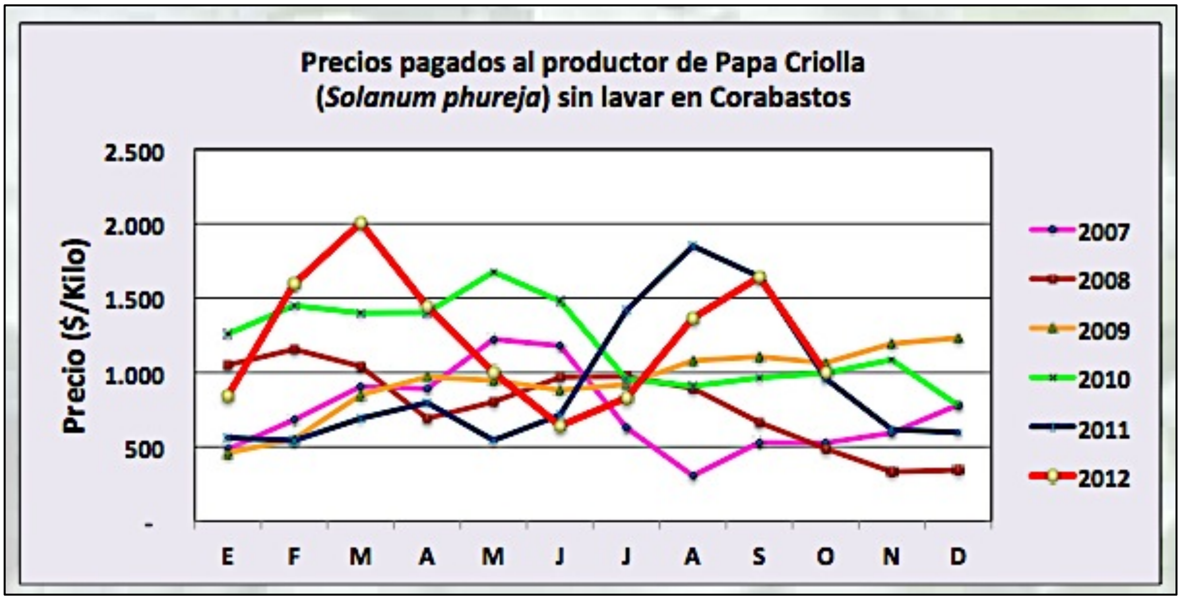

Figure 3: Monthly Sales Price (per Kilo) for the Criolla Potato Variety from 2007-2012[3]

The biggest challenge of all for farmers is in the fight against the many diseases that plague the potato crop. There are over 35 *common* types of pests, fungi, bacteria and virus' that can affect the health and growth of the potato (FEDEPAPA, 2012). The three major afflictions include: the Andean weevil, the late blight fungus, and the Guatemalan potato moth. Furthermore farmers have to resort to harmful pesticides in order to reduce crop destruction.

The Guatemalan potato (*T. Solanivora*) moth is one of the most harmful pests to attack potato crops in Colombia. It has the ability to destroy entire stocks of potatoes (in the field and in the storage) in less than three months by drastically reducing the quality of the tubers (European and Mediterranean Plant Protection Organization EPPO, 2005). Potatoes that are infected cannot be sold for human consumption and are primarily used to feed the livestock. As a result, they can only be sold at a fraction of their usual market price. The end result is that farmers incur huge losses, which often prevent them from covering their costs. Furthermore, the pest is very resilient and can survive between cropping seasons in any discarded potatoes that remain in the soil after the harvest, and in any potatoes that are held

[3] *Source: Federacion Colombian de Productores de Papa. Revista Papa. 2012 http://www.fedepapa.com/wp-content/uploads/pdf/revistas/ed26.pdf*

in storage (Wale and Cattlin, 2008). This means that a single infestation in one year can also result in the destruction of future yields.

Farmers use a wide range of insecticides to control for the Guatemalan Potato Moth. Some substances are extremely toxic to humans, animals and the environment. One such pesticide is Carbofruan. The use of Carbofuran is currently banned in Canada, the European Union and most recently in the United States (U.S Environmental Protection Agency EPA, 2011). It is highly toxic by inhalation and can have the effect of over-stimulating the nervous system causing nausea, dizziness and confusion (International Program on Chemical Safety, 2012). This pesticide is also detrimental to the surrounding environment, particularly to the animal population.

More commonly used in Colombia are a second class of insecticides, which are slightly less toxic than the first. In order for the side effects of these substances to remain minimal, adequate protection measures must be taken. This is not always the case in Colombia. Chlorpyrifos is an example of one such pesticide. The EPA (2011) finds that chlorpyrifos can have negative side effects including muscle weakness, intestinal discomfort and fatigue. These effects can generally be prevented if the appropriate measures are taken: respecting a 24-hour waiting period before entering fields where chlorpyrifos have been applied, using chemical resistant gloves, chemical resistant shoes plus socks, chemical resistant headgear for overhead exposure (Agency For Toxic Substances and Disease Registry, 2011). More often than not, Colombian farmers do not follow many of these measures. Moreover, the farmers' families generally live close to where the potatoes are grown, making them particularly vulnerable to the chemicals that are systematically applied to the crops.

One of the goals of this study is to arrive at a better understanding of Colombian farmers' attitude towards pesticides. Therefore we also look at pesticide use, protective measures and pesticide related illnesses among potato farmers in the department of Cundinamarca, Colombia. More specifically, 183 farmers were asked to reveal whether they had suffered pesticide related illnesses in the last five years, and to indicate which measures they had taken to protect themselves from these pesticides. Just over 75% of farmers have experienced a serious illness in the last five years. This includes severe headaches, severe nausea, difficulties breathing, and skin irritations. The most common ailment are headaches followed by nausea and respiratory problems. Most farmers are aware of the health effects that long-term exposure to pesticides can cause.

The majority of farmers in the sample use some form of protective measures when applying pesticides to their crops. At first glance the data suggests that farmers are very conscious of using the appropriate gear to shield themselves from toxic chemicals. Nevertheless, this information can be misleading. While close to 85% of farmers use some form of a mask, the majority of farmers only use a simple piece of cloth. According to the International Labor Organization (1991), every mask needs to contain a filter, which should be changed regularly. Farmers must ensure that the mask fully covers their nose and mouth. This is especially relevant for Colombian farmers because they apply pesticides by means of a lever-operated knapsack sprayer. These farmers are in such close proximity to the chemicals, that insufficient respiratory protection means they are potentially exposed to high dosages of the pesticide.

The ideal type of mask covers the entire face and resembles a gas mask. Less than 10% of farmers in the sample use such a mask. Furthermore, close to 40% of farmers do not use some form of work clothes (coveralls) when they apply pesticides. Moreover, of the 60% that do report using coveralls, many do not take all the necessary precautions to keep these work clothes from coming into contact with objects from their daily lives. For example, it is common for farmers to come into the house for lunch during the day wearing the same clothes they sprayed the fields with. In doing so they inadvertently bring the chemicals into their homes. Finally, less than 15% of farmers in the sample use glasses. This is an extremely important protective measure as some chemicals can cause severe long-term damage to the eyes.

There exist other studies that confirm this fairly relaxed use of preventive measures by Colombian farmers. Most recently, Feola and Binder (2010) surveyed 190 potato farmers in the region of Boyacá in order to determine the factors that would encourage the use of protective equipment. They found that less than 50% of their sample wore some form of facial protection while 41% wore gloves and 23% wore specific work clothing. Finally, less than 3% wore goggles.

II. Integrated Pest Management and Push-Pull technologies

The struggle against pests is one that Colombian potato farmer's share with other farmers across the world, and particularly with smallholder farmers in other developing countries. Common are the stories of farmers choosing to use pesticides that are harmful to their health and the environment, in order to try to protect their yields.

In an effort to address this pressing issue, scientists worldwide have made a concerted effort to establish new agricultural technologies that are more environmentally friendly and more efficient than pesticides. One such technology is known as integrated pest management (IPM). IPM requires the use of plants and other natural organisms, rather than pesticides, to deal with the insects that attack farmers' crops. Many scientists have experimented with IPM and its success is well documented (Norris et al., 2003). They have established that the technique is well suited to many different environments (Radcliff et al., 2009). More specifically, reports indicate that yield levels are either maintained or significantly increased while reducing the use of pesticides and increasing the benefits for the environment and human health.

There are many different types of IPM strategies that control for crop pests and diseases. One application of IPM that has generated very positive responses is the *push-pull* technique, with experiments in Kenya reporting the highest success rates. The idea behind the *push-pull* strategy is to combine two different types of organic stimuli in order to rid the production crop of a particular harmful insect. The first stimuli, referred to as the *push* stimuli, drives the pest away from the production crop while the *pull* stimuli attracts the pests and neutralizes it. The observed increases in maize yields in Kenya were dramatic. Khan et al. (2008) produced an in – depth cost benefit analysis to illustrate the benefits of this technique. They demonstrate how the push pull strategy is economically efficient, generates greater yields and provides better returns to land and labor.

IPM and more specifically *push-pull* strategies are highly context-specific. The particular stimuli (traps and repellants) that succeed in one environment are not guaranteed to work in another. It is critical for scientists to understand the exact nature of the pest, and its environment, in order to establish how IPM can be correctly administered in that given setting. Therefore the Kenyan push-pull strategy for example can not be directly applied in Colombia with the same results. Nevertheless, in searching for a way to deal with the Guatemalan potato moth, Poveda and Gómez (2009) began designing a new push-pull strategy for potato crops in Colombia in 2009. They effectively combine the use of a spray repellant (a mixture of garlic and pepper extract) and a trap plant (a different variety of potato plant, S. tuberosum cv Roja Narino) that successfully neutralizes the moth. The technology presents a number of clear benefits to the farmers: it protects their crop yields while reducing their exposure to harmful pesticides and preserving the surrounding environment. At the time of this study Poveda was in the process of running some final tests to ensure that the technology was effective under different environmental conditions.

While this new technology is beneficial for a number of reasons, it is unclear whether Colombian potato farmers are interested in investing in new agricultural strategies. Indeed, these technologies may involve certain objective and subjective risks, they also may require more time and labor in order to learn how to implement them. For these reasons it becomes important to assess which factors might encourage Colombian farmers to adopt these valuable technologies. In particular, it is worth exploring whether risk preferences have an important role to play.

Section III: Literature Review

The previous section provides the main motivation for this study: Colombian farmers are struggling in the face of many challenges and could benefit greatly from new technologies that protect their yields and reduce the amount of harmful pesticides they have to handle. Poveda and Gómez (2009) discovered one such technology and were in the process of running some final tests at the time of this survey. Our main objective is to understand the factors that will impede the adoption of technologies similar to the one developed by Poveda and Gómez (2009). In particular we are interested in knowing whether risk preferences have a role to play.

We conduct our analysis before this particular technology was ready to be diffused. As mentioned previously, this is done purposefully in order to provide valuable information to scientists and policy makers. The former can use this information to refine the technology based on farmers' preferences, while the latter can try and address any social barriers to adoption. As a result we need to measure farmer's *willingness* to adopt and gather enough information on the two primary barriers of adoption that we identify, namely features of the new technology and characteristics of the farmer.

This section goes through the four different bodies of literature that we use to design and structure this study. The first part of the section reviews the methodology used to identify stated preferences. We rely on this literature to design the choice experiment (CE) and the contingent valuation (CV) question, which provide measures of farmer's willingness to adopt a new technology, and the extent to which they will adopt. The CE is also used to identify the attributes of a technology that farmers find most attractive. We then summarize the literature on technology adoption in order to identify other potential barriers of adoption. This informs the design of the questionnaire which was administered to farmers along with the CE. Thirdly, we devote a section to the small number of studies that specifically determine the influence of risk preferences on the decision to adopt. Finally, we review the literature on experimental games as they pertain to risk. This is necessary to determine the most efficient way of measuring farmers' risk preferences.

I. Stated Preference Methods: Willingness to Adopt and Extent of Adoption

Our approach to answering our primary questions of interests is to draw on different bodies of literature from various fields in economics. Firstly, we provide an overview of the literature concerned with stated preference methods. Indeed, this paper draws heavily from the body of literature that deals with Stated Preference (SP) methods. In SP surveys, researchers present hypothetical questions to their subjects in an attempt to infer their preferences for, or the value they place on, certain goods or services. These questions require that individuals make tradeoffs between different attributes of the good/service, or between the good/service and a particular monetary sum.

Stated preference methods are valuable for a number of reasons. Firstly, they provide a unique way for economists to estimate preferences for goods and services when markets do not yet exist. This occurs frequently in environmental economics, as researchers try to identify the value humans place on wildlife and natural resources. Secondly, SP methods are often the only practical approach for measuring preferences over goods or policies prior to their diffusion or implementation. Many government institutions for example would like to measure how individuals will respond to a certain policy. While their behavior cannot be monitored directly, the results from an SP experiment can provide some accurate predictions about which attributes of the policy will be accepted or rejected.

The purpose of the following section is to provide an overview of the wide range of SP methods employed in the literature. This will then allow us to justify the two measures that were selected to evaluate Colombian farmers' willingness to adopt a new technology and extent of adoption.

A. An overview of Stated Preference Methodology

The two most prevalent forms of preference elicitation are referred to as contingent valuation and choice experiments. On the one hand, (CV) methods tend to refer to a stand-alone binary choice task, which requires that subjects state their preference between the status quo and a *single* new policy, good or service that has some additional benefit, at a greater cost (Carson, 2007). These costs can be varied in order to map out the subject's willingness to pay (or accept) for that policy, good or service. On the other hand, CEs present subjects with *various sets* of competing alternatives that differ based on specific attributes. The respondents are then asked to choose among them, thereby revealing his or her overall preferences and the value he or she places on the specific attributes. [4] According to the pioneers of CE, CE is simply an extension of CV (Adamowizc et al., 1998). More specifically, while CV methods only focus on a choice between a base case and a specific alternative, CEs asks people to choose between alternative cases that are described by attributes. This difference bestows the CE with some unique advantages, to be detailed below.

Before moving onto a more detailed overview of CV questions, CEs and their differences, it is worth mentioning that both these structures can be analyzed using a random utility model. This is the model we employ in the current paper as well. In each case the subjects' choice of an alternative (yes/no in the CV question and one alternative over another for the CE) can be represented as a discrete choice between two options. In this context, each alternative is described by a utility function, which is comprised of a deterministic element and a random error (Train, 2009). The subject chooses a specific alternative if the utility they derive from it is greater than the utility they would gain from any other choice. Assumptions regarding the distribution of the error terms then dictate how the probability of choosing the "i^{th}" alternative can be estimated (Train, 2009).

CV questions provide subjects with a detailed description of a policy, good or service. The design of a CV question induces subjects to reveal how much they value the policy, good or service in monetary terms. There exist different forms of CV methods, but by far the most prevalent is the dichotomous choice CV (Haab and McConnell, 2004). Dichotomous choice CVs use a close ended format, asking subjects to answer yes or no to questions of the form "Would you be willing to pay/accept x dollars for this service/good/policy". There are different types of dichotomous choice methods. The single bound (SB) dichotomous choice version asks one question to respondents of the form detailed

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[4] It is worth mentioning that CV's can also be used to value multiple goods and their changes in attributes (e.g., Randall et al. 1974). Nevertheless, according to Lusk (2004) they require "cumbersome repeated questions to achieve the same level of complexity".

above. The SB method used to be heavily used in the literature, but it has been steadily replaced by the double bounded dichotomous choice (DB) method. Indeed, Hanneman et al. (1991) successfully demonstrate that the statistical efficiency of the SB model can be improved by asking each subject a second question, which depends on their answer to the first. If respondents answer, "yes" to the first question they are offered a higher bid. Conversely if respondents answer "no" to the first question they are offered a lower bid. Finally some have argued in favor of the one and a half bound dichotomous choice method (OOHB). In a second paper Hanneman et al. (2002) show that the OOHB, while slightly less efficient than DB, provides consistent estimates, which is not always the case for the DB. For that reason we chose the OOHB model.

A CE is "a general preference elicitation approach that asks agents to make choices between two or more discrete alternatives where at least one attribute of the alternative is systematically varied across respondents in such a way that information related to preference parameters of an indirect utility function can be inferred" (Carson, 2000). The most commonly used CEs are sequential and present a *series* of choice sets, where each choice set is made up of two or more alternatives. We opt to use a binary choice question (only two alternatives), which asks farmers to choose between two technologies: the status quo and a new hypothetical alternative. The advantage of including the status quo is that it makes it easier to assess changes in welfare. Indeed, the respondents always have the implicit option of choosing the status quo alternative and, as a result, it should also appear formally in the choice set of the CE (Carson, 2000).

The ideal CE uses a full factorial design, which combines every level of each attribute with every level of the other attributes. Each combination forms an alternative and hence the experiment produces every alternative that could possibly arise from the different attributes and their levels. These designs are not always practical in applied research. As the number of attributes and levels increase, the number of potential alternatives becomes too large to manage. As a result, the literature has turned to fractional factorial designs, which selects a fraction of these alternatives in such a way as provide uncorrelated estimates of all main effects (Addelman, 1962). This will be used in the current paper as well.

CEs present a number of clear advantages over CV methods. The reasons detailed below help explain why we opt to use the CE over the CV to understand farmers' willingness to adopt a new technology. Nevertheless we do make use of a CV question in order to investigate the role of risk preferences on the extent to which farmers adopt. This is done for practical reasons that will be detailed later in the paper.

Firstly, CEs typically ask respondents about a sample of events rather than a single event (Boxall et al., 1996). This provides the researcher with more detailed information about how subjects will behave and make choices under a variety of different circumstances. Furthermore, in CEs, subjects are encouraged to focus on specific attributes of the goods or services rather than on the details of a given case (Louviere et al., 2000). The attributes of the CE are laid out in tabular form whereas the details of a specific case in the CV are usually described in a paragraph. As a result, researchers can be sure that the subject is focusing on the particular aspects of the commodity that matter the most to the study. The same cannot be accomplished with a CV.

Secondly, CEs presents some logistical advantages over CV methods. Indeed CEs are less prone to strategic behavior on the part of the subjects (Louviere et al., 2000). In CE's subjects must make a series of choices one after the other, which makes it harder to follow a specific strategy. Conversely with CVs, the subject might understate their willingness to pay for a good or service in the hopes of seeing its price drop. Furthermore, it is much easier to detect inconsistent behavior in a CE than in a CV question. The CE elicits repeated responses from each subject and varies the levels of each attribute; thereby allowing researchers to analyze the choices made and make sure they are consistent with one another.

Most importantly CEs provide detailed information on subjects' valuation of each attribute and the trade-offs they are willing to make *between* the attributes (Adamowicz et al., 1998). In the case of damages to a particular attribute for example, compensating amounts of other attributes (rather than a monetary compensation) can be calculated. While CV questions can also be used to value multiple goods and their changes in attributes (Randall et al. 1974), this can be fairly complicated to achieve. According to a number of experts (Adamowicz et al., 1998; Lusk 2004) the CV design would have to ask a large number of questions in order to tease out all the same effects that the CE is able to identify. It would also be difficult to ensure that some degree of orthogonality was maintained in the design.

B. Application of SPM: Technology Adoption

Stated preference methods have been widely used in various fields of research including transportation, marketing and health. Nevertheless, there are only a few studies to date that have applied SP towards understanding technology adoption in agriculture. This next section offers an overview of this growing body of literature. It will show how the majority of the papers use dichotomous choice CVs (with one exception) in order to estimate farmers' willingness to pay for a new technology. Moreover the summary will show that most studies use WTP versus WTA measures. Finally the review will distinguish between the papers that include revealed preferences in their models, and those that do not.

i. Willingness to Pay (WTP) and Technology Adoption

The first two papers of interest combine revealed and stated preferences methods in order to measure farmers' attitudes towards a relatively new technology in the cotton industry: BT cotton. This information is then used to construct demand curves for BT Cotton, which depend on the probability of adoption and the proportion of land allotted to BT cotton if adopted.[5] The proportion of land devoted to BT cotton is a reflection of the extent to which farmers are willing to adopt a new technology.

The first paper by Qaim and de Janvry (2003) examines why adoption rates in Argentina have remained so low despite the technology's many established benefits. The second paper by Hubbell et al. (2000) focuses on the cotton industry in the Southeastern regions of the United States and hopes to inform policy on how to best expand BT cotton's use. The sample of farmers in both studies includes adopters and non-adopters of BT Cotton. The adopters, having already made their purchases of BT cottonseeds, explicitly *revealed* their preference for the new technology at the market price. Conversely, the non-adopters' preferences were measured via contingent valuation methods.

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[5] The demand curve can be predicted as Q_d=ASHARE*BTPROP*TOTCOT*ERROR. ASHARE is a variable that predicts the share of farmers likely to adopt BT cotton at different price levels. This is derived from the WTP model. BTPROP is the area that adopting farmers would cultivate with Bt cotton at the price. This is estimated using a Heckit model (to correct for the non-random selection bias). TOTCOT is the total cotton area in the country observed in the reference year (Qaim and de Janvry, 2003).

Both studies make use of random utility models, to which they apply maximum likelihood techniques in order to estimate farmers' willingness to adopt BT cotton. Qaim and de Janvry (2003) find that farmers' average WTP for BT cotton is less than half the actual market price. Secondly, the authors are able to show that education, information received about BT cotton and land size have a positive effect on the probability of adoption, whereas credit constraints, and higher prices for the GM seeds, have a negative effect. Finally, they find that the proportion of land that farmers are willing devote to BT cotton depends on the price of the new technology, education levels and cost of insecticides. Hubbell et al. (2000) establish very similar results in the US, although there exists some noteworthy differences. For example, they find that the average WTP in the United States is close to the market price, and higher than the WTP in Argentina. Moreover the authors determine some additional factors influencing adoption, which include location in the US, and experience with resistance to conventional pesticides. Finally, Hubbell et al. (2000) show that the price of the new technology, famers' income and their experience with conventional pesticides affect the amount of land farmers devote to the new technique.

The previous studies creatively combine survey data on stated *and* revealed choices in order to better understand farmers' preferences for a relatively new technology. While this approach is very effective, it cannot be used to understand how smallholder farmers will interact with a new product that has yet to be introduced on the market. The following two studies make use of stated preference methods only, in an attempt to tease out farmers' preferences for new technologies that have yet to arrive on the market.

The first paper by Krishna and Qaim (2007) investigates eggplant producers' WTP for a new BT seed that has yet to be released. More specifically, the authors use a double bounded dichotomous choice model in order to examine how farmers' WTP will fluctuate depending on market conditions. The authors establish that farmers' average WTP for a *proprietary BT hybrid* seed will be four times the price of conventional hybrids (due to the seeds' many attributes). Moreover, the study predicts that when a cheaper BT seed (*BT OPV*) also hits the market, mean WTP for *proprietary* BT hybrids will decrease.[6] The paper also identifies the main factors favoring adoption of BT seeds. These include: high pesticide expenditure, cultivating owned (not leased) land, higher income, greater household size, (as a proxy for labor availability), greater exposure to pest infestations, and receiving agricultural advice from private (rather than government) dealers.[7]

The second paper by Kolady and Lesser (2006) also examines WTP for BT *hybrid* eggplant seeds (provided by a private company) versus BT *open pollinated variety* (OPV) seeds (provided by a public institutions) in a different Indian province. The authors run a slightly different double bounded dichotomous choice model to assess WTP for the BT hybrid, and an additional simple open-ended question to measure WTP for the BT OPV.[8] The main decision framework they present is comprised of two dichotomous decisions. The first decision (already made by farmers) is between conventional hybrid seeds and conventional OPV seeds. The second choice is hypothetical, to be made between BT seeds (*hybrid and OPV)* and non-BT seeds. The authors find similar results to Krishna and Qaim (2007) by using a bivariate probit model for estimation. The resource-limited farmers that already use conventional OPV seeds are more likely to adopt BT OPV seeds, while the wealthier, educated, large-scale farmers that already use conventional hybrids, will opt for the BT hybrid.

ii. Willingness to Accept (WTA) and Technology Adoption

The previous studies estimated farmers' willingness to pay for a new technology and predicted their likelihood of adoption. In some cases, however, it might not be useful to calculate WTP. Indeed farmers might be too risk averse or lack sufficient information on the new practice to consider investing their time and resources into it. The important question then becomes whether or not the farmer can be incentivized to adopt.

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[6] A variation on a choice experiment was used to determine how farmers' behavior would change under a new market structure, where they are faced with three distinct choices: (i) adopting Bt hybrids (produced by the private company), (ii) adopting Bt OPVs (produced by the public sector), and (iii) non-adoption of the technology.
[7] There are additional factors motivating the purchase of BT hybrid over BT OPV. The results indicate that BT hybrids caters to larger, more wealthy farmers while BT OPV seeds are better suited to poorer farmers with less resources.
[8] The authors also ask farmers to state their preferences directly between BT OPV and BT hybrid if both were available on the market.

The following paper by Cooper and Keim (1996) examines the efficiency of a USDA funded program that offers 10$ incentives for every new acre that a farmer devotes to environmentally friendly production practices. The authors begin by using a double bounded dichotomous choice CV to elicit farmers' willingness to accept.[9] Farmers that opted to try the new technology for a certain dollar amount were also asked to indicate how many acres they would devote to the new farming practice. The authors use a bivariate probit model to assess the probability of adoption.[10] Moreover, a bivariate probit sample selection model, and a double hurdle model, are both used to determine what factors affect the decision to devote more or less land to the new farming technique.[11] The paper finds that farmers are more willing to adopt if the amount they will receive from the USDA is higher, and if they invest little time in off-farm work. Moreover farmers with more land, higher net income and less off farm work are willing to devote a higher number of acres to the new farming practice. The authors conclude that it will be very expensive to incentivize farmers to switch to a new technology. At current rates of 10$ only 30% of farmers will accept enrollment.

iii. Choice Experiments (CE) and Technology Adoption

The choice experiment is arguably the most appropriate stated preference method to understand technology adoption. It allows researchers to obtain a precise measure of a farmer's willingness to adopt, and simultaneously identify which attributes of the given technology farmers find most attractive. Breustedt et al. (2008) design a multinomial choice question in order to explore farmers' willingness to adopt genetically modified oil seed rape in Germany. The authors use a random utility framework, which is estimated using a multinomial probit. They find that the specific attributes of the GM technology significantly influence the probability of adoption. Moreover the authors identify a number of farm and farmer characteristics that impact the decision to adopt a new GM technique. Finally the study presents

[9] The specific question is "if you don't use this practice currently, would you be adopt the practice if you were given a $[X] payment per acre? (answer yes or not)

[10] This accounts for the sample selection bias that may exist. Indeed, only those survey respondents who had not yet adopted the farming practices were asked the CV question.

[11] A double hurdle model is a bivariate probit sample selection model with a tobit structure for the continuous portion

demand simulations, which illustrate how sensitive adoption is to the profit margin differences between GM and non-GM rape varieties.

II. Determinants of Technology Adoption: General Overview

SP methods have been used to establish whether or not individuals will adopt a new technology in the future. They can also be used to identify potential barriers to adoption. Choice experiments in particular help to determine which specific attributes of a given technology will most likely increase the probability of adoption. For example, some farmers will only switch towards a new technology if yields are twice as high, while others are content with slightly lower yields if they can be sure that the new technique is more environmentally friendly. This information becomes especially useful to scientists who can then adjust the features of the technology based on farmers' preferences.

The use of SP methods requires that researchers collect their data before the technology is actually diffused (*ex-ante)*. As we have seen, there are only a handful of studies that use this approach to analyze the decision to adopt a new technology. Indeed, the majority of papers that investigate technology adoption do so after diffusion has taken place (*ex- post)*. The following section reviews this large body of works. The literature is extensive because the decision to adopt a new technology is complex. The choice depends on a number of variables that extend beyond farmers' attitudes towards the specific features of the new technique. Indeed, the literature has extensively documented the importance of social factors. This includes a farmer's level of education, their social networks, liquidity/labor constraints, and risk. The following sections summarize the main papers that have explored these factors' impact on technology adoption.

A. Learning by doing and Learning from others (Networks)

Within developing countries, the diffusion of new technologies generally takes place at the village level. Farmers begin to discuss the features of the new technique amongst themselves, and some will choose to adopt while others will not. There are two ways to learn about the new technology. Firstly farmers can try the new technique for themselves and gain experience and confidence that they will be able to generate higher yields and profits. Secondly, as diffusion starts to pick up, the process of learning about the new technology becomes increasingly social. New users learn the characteristics and the methods from other adopters in their social network. There is a growing body of literature that has tried to measure the importance of learning by doing, and learning form others, on the decision to adopt.

The first study to look at the effects of learning on technology adoption was conducted by Besley and Case (1994) in India. They develop dynamic models of learning, where farmers update their preferences based on the profits (or losses) they incur from using the technology, and their perceptions of the technology's value. The models are then used to simulate the various decisions that farmers might make in response to the appearance of a new technology. The study finds that farmers do learn from others and that adoption of high performance seeds is correlated with adoption among their neighbors.

Subsequently, Foster and Rosenzweig (1995) assess the relationship between social networks and technological change as it pertains to high yielding seed varieties (HYVs). They develop a target input model that incorporates learning by doing, as well as learning spillovers from others. The model is then used to derive testable hypotheses about these learning processes among rural farmers in India during the Green Revolution. They find that farmers with insufficient information about the new technology are much less likely to adopt HYVs. Secondly, as farmers and their neighbors' gain more experience with the new technology, the likelihood of adopting increases. Moreover, they begin to derive higher profits from using the new technique. Barrett and Moser (2006) and Conley and Udry (2010) identify two main drawbacks with this paper. Barrett and Moser (2006) criticize the model's assumption that adoption is optimal and that farmers will never dis-adopt. Conley and Udry (2010) on the other hand illustrate the drawback in having to use village aggregates as the relevant information for social learning.

In the last decade there has been a renewed interest in the effects of social learning on technology adoption. Munshi (2004) develops a model, which illustrates that the effectiveness of social learning depends on the diversity of the population. The study demonstrates that the flow of information is weaker in areas where farmers are more heterogeneous, especially when the technology's performance is sensitive to neighbors' unobserved characteristics. Furthermore, Bandier and Rasul (2006) analyze social networks and technology adoption in Mozambique. The novelty of their study resides in the fact that they were able to contact farmers precisely when the technology began to be diffused in the region. This allows them to isolate the characteristics of the first adopters, as well as identify whether social networks influence the decision to adopt. They find that farmers are more likely to adopt when they have *a few* other "adopters" in their network. Conversely if farmers have a network consisting *primarily* of other adopters, they themselves are less likely to adopt (possibly because they chose to free-ride). Finally Barrett and Moser (2006) conduct a study of technology adoption in Madagascar. This paper will be explained in greater detail below. To summarize briefly, they find that farmers with higher levels of education, and greater access to extension agents, are more likely to adopt. Similarly, farmers who belong to cooperatives, and thereby interact more frequently with other farmers, are also more likely to adopt.

Conley and Udry (2010) recently published one of the most influential papers on social learning and technology adoption. Their research is set in Ghana among pineapple growers, a region where new technologies re rapidly emerging. The authors create a unique data set, which maps out each farmer's information network by tracking their communication patterns with others. Furthermore, the authors collect geographical data as well as information on farming characteristics, soil composition and household demographics (family relationship and credit access) in order to mitigate the likelihood of omitted variable bias. They find that farmers will increase (decrease) their use of fertilizer if one of their neighbor's had a better than average harvest when they used more (less) fertilizer.

In this study we also attempt to identify the effects of social networks on the decision to adopt. Our measures are very basic though as we are working with cross sectional data. More specifically, we include two variables in the model that exemplify the idea that farmers learn from others. Indeed, we asked farmers whether they sought advice from other farmers and/or extension agents.

B. Seasonal Liquidity and Labor Constraints

Another main barrier to adoption includes seasonal liquidity constraints. This is most dramatically illustrated by Barrett and Moser (2006), who analyze the decision to adopt a system of rice intensification (SRI) in Malaysia. They design a complex model of technology adoption in order to understand why adoption rates have remained so low. The authors also collect recall data in order to generate a quasi-panel data set. Their framework is based on the standard model of inter-temporal utility maximization. They subsequently estimate the decision to adopt and the extent of adoption using a probit and a tobit model (using Powell's symmetrically censored least squares estimator), respectively. The paper finds that farmers' liquidity is a major factor hindering adoption of SRI. Indeed farmers often run out of their supply of rice in the months leading up to the harvest. In the absence of seasonal credit these farmers are constrained to sell their labor and work on neighboring farms in order meet their basic subsistence requirements. As a result households face a shortage of family labor, which then deters them from adopting a new technology such as SRI, which requires greater amounts of labor.

There are a number of other studies that identify credit constraints as a barrier to adoption. Croppenstedt, Demeke and Meschi (2003) estimate a double hurdle fertilizer adoption model among farmers in Ethiopia. They find that insufficient access to credit is the major supply side barrier to adoption. Furthermore, there are also theoretical models developed by Feder (1980) that highlight the negative impact of credit constraints on adoption decisions. More precisely, when credit constraints are binding and farmers experience an increase in credit availability, they devote more of their resources to the new technology.

It is unlikely that credit constraints will be of the greatest importance in this study for several reasons. These will be detailed later in the analysis section of the paper. In general, however, farmers have relatively easy access to credit from various financial institutions.

C. Risk

Finally we provide a detailed overview of the literature that investigates the effects of risk preferences on technology adoption. Because this is the focus of our current paper as well, we dedicate a separate section to this review.

III. Determinants of Technology Adoption: Risk

There exists a substantial body of works that investigates the relationship between risk and technology adoption. Some of the studies are rooted in theory while others use experimental games and survey questionnaires to specifically measure individuals' risk preferences and their decisions to adopt. The following section provides a brief overview of the most influential papers in the field.

A. Structural Models of Risk on Technology Adoption

Theoretical models have long explored the effects of risk on adoption decisions. Just, Feder and Zilberman (1985) provide a detailed review of the various models that have emerged over the years. The first group of models addresses a scenario in which farmers choose between the traditional technology and a modern one. Hiebert (1974) develops a model of this type. Assuming that farmers are risk averse, he investigates the impact of imperfect information on the decision to adopt. He uses a stochastic production function, and finds that increasing levels of risk aversion induce the farmer to devote less land and fertilizer towards the modern crop. Subsequently, in 1980, Feder presented a new framework. His model is anchored in the assumption that only the new crop has some measure of uncertainty associated with it. Moreover this new crop does not require any additional fixed costs. Feder also assumes risk aversion and makes use of a stochastic production function. The model predicts the same results for land allocation as Hiebert's. However, it does not find that fertilizer usage was influenced by risk aversion. Later, in 1983, Just and Zilberman built on Feder's 1980 study. They demonstrate that the decision to invest more or less heavily in modern inputs depends on two independent factors. Firstly it is contingent on whether the new technology is risk reducing or risk increasing. Secondly it depends on whether relative risk aversion is increasing or decreasing.

The models previously discussed are static adoption models, and assume that the farmer has to make a single decision between two technologies. In their review Just, Feder and Zilberman (1985) also identify a number of other models that extend beyond this one time decision framework. Indeed, Feder (1982) develops a model where farmers have to decide between the status quo and two modern technologies. Farmers can choose to adopt one or both of the new technologies. The model finds that the decision to adopt one technology or both depends on different factors, because the technologies involve varying amounts of uncertainty and risk.

Finally, Just, Feder and Zilberman (1985) also present a few studies that use dynamic models. In this framework, farmers update their opinions of the new technology based on their past experiences. O'Mara (1971) produces one of the first models to use scientific Bayesian methodology. In the model, producers adjust their beliefs based on the technology's performance. Indeed, if producers find that the new technology is doing well, they tend to invest more heavily in it. In other words, the more positive experiences these producers have, the more likely they are to increase their extent of adoption. Subsequent dynamic models have also included risk preferences. Linder and Fischer (1981) develop a complex Bayesian learning model, which assumes risk aversion.

B. Experimental Studies of Risk on Technology Adoption (after diffusion)

Just, Feder and Zilberman's seminal paper (1985) discusses the various different theoretical models of technology adoption that feature risk. The study also provides a brief review of the empirical studies that have investigated the impact of risk preferences on technology adoption. They acknowledge that at the time of publication (1985) only two studies had successfully related risk and technology adoption empirically. This research was conducted by O'Mara (1980) in Mexico and Binswanger (1980) in India. In the last 10 years there have been a few more studies that further investigate this relationship.

The first studies to analyze the impact of personal risk preferences on the decision to adopt, use very broad measures of technology adoption. Some also use rather basic calculations to estimate farmers' level of risk aversion. Knight, Sharada and Woldehanna (2003) explore the effects of education on risk preferences, and the decision to adopt a new technology. More specifically, the authors investigate whether education impacts the decision to adopt directly, or indirectly through its effect on risk preferences. They measure risk using a single hypothetical question, which asks farmers to choose between a safe and risky alternative. Farmers are then categorized into two groups: those who are risk averse and those who are not. Furthermore the authors choose a dichotomous measure for technology adoption. If farmers have adopted what the study refers to as an "innovative" input and an "innovative crop" they are given a score of one. Conversely if the farmer has only adopted one of these two innovations, or none at all, they are given a score of zero.   The study finds that higher levels of education decrease risk aversion, while both risk aversion and education directly increase the probability of adopting a new technology.

Warnick, Escobal and Laslzo (2011) use a more complex process to categorize farmers' risk preferences.   Indeed, they use several experimental games, based on Holt and Laury's (2002) designs, to determine farmers risk preferences and their attitude towards ambiguity.[12] The authors then construct a portfolio choice model to derive testable predictions about the effect of risk preferences and ambiguity on farmers' decision to diversify the *type of* crops they cultivate, as well as the *varieties* of crops they use. Turning to the data, they find that farmers who are more averse to risk and ambiguity are less likely to diversify they *type* of crops they harvest. Moreover, they find that while risk aversion is not statistically significant in predicting the decision to try new *varieties* of a *known* crop, ambiguity aversion is.

The previous studies do not focus on a specific technology, and therefore innovation is rather arbitrarily defined. It then becomes difficult to isolate why farmers did not adopt the new technology. Indeed it could be that they were risk averse, or it could also be that they believed the technology was inefficient. In this case non-adoption may simply reflect the fact that farmers did not find it profitable to try these new techniques.

Liu (2012) recently conducted one of the most complex empirical studies to examine the relationship between risk and technology adoption. The study examines a group of cotton farmers in rural China who must choose between planting traditional cotton seeds or genetically modified, BT cotton

[12] The distinction between risk and ambiguity is the following. Adopting a new technology requires taking on some risk because the farmer is uncertain about how the new technology will perform. A farmer is aware of the fact that the new technology may either generate high or low yield but they do not know which outcome to expect. They must be prepared to take on some risk because of this uncertainty. Ambiguity refers to the situation where farmers are unaware of the probabilities associated with the high and low outcomes of the new technology.   Therefore, "the uncertainty is about the yield probabilities, in addition to the uncertainty about which state of the world will realize. This is the ambiguity case".

seeds. Over the past ten years some farmers have adopted the new technology (GM seed) while others have not. The author designs a clear model of technology adoption that incorporates farmers' subjective risk in order to test the main hypothesis that risk influences the probability of adopting. The measure of technology adoption that is used is the year in which farmers decided to adopt BT Cotton. Furthermore the study uses a sophisticated experimental game designed by Tanaka, Camerer and Nguyen (2010), in order to identify farmers' risk preferences. These games can also be used to estimate farmers' aversion to losses, and derive a measure for how subjects weight probabilities. Liu finds that farmers who are more loss averse and/or more risk averse adopt Bt cotton later. Conversely farmers who overweight small probabilities tend to adopt Bt cotton earlier.

Liu's study is truly innovative. Nevertheless it suffers from one limitation: the data is cross sectional and the experimental games were conducted after farmers had adopted BT cotton. Therefore these *ex-post* measures, namely farmers risk preferences, could be affected by the decision to adopt the new technology. This endogeneity problem is hard to correct for given the constraints in the data.

C. Our approach: Experimental Study of Risk on Technology Adoption (before diffusion)

This paper ads a new dimension to the literature on risk and technology adoption. Indeed, it is the first study to investigate the impact of risk preferences on farmers' *willingness* to adopt a new technology, as measured by stated preference methodology. While there are a few papers that investigate the impact of risk on the decision to adopt, this is the first study to do so before the technology is actually diffused. One of the reasons for taking an ex-ante approach is to inform policy makers of whether or not individual risk preferences will interfere with farmers' decision to adopt. Implementing partners can then use this information to address farmers concerns before diffusion takes place and thus ensure higher adoption rates.

IV. Eliciting Risk Preferences

In light of the foregoing review, we will now provide a summary of the literature that investigates how to obtain a measure of risk preferences.

A. Experimental Games using Expected Utility Theory

Over the past thirty years, economists have established that experimental games provide the most effective way of assessing individuals' attitudes towards risk.[13] Moreover, these games are almost exclusively grounded in Expected Utility (EU) Theory. In his seminal paper, Binswanger (1980) measures risk attitudes among 240 households in rural India. The subjects are presented with eight different gambles. Each gamble consists of one high payoff and one low payoff, with equal probability of landing on either outcome. Furthermore, each gamble reflects a different degree of risk aversion. Individuals are then given a risk coefficient based on a constant partial risk aversion function. This exact set up is repeated multiple times by increasing or decreasing the level of each payoff in the game by a constant factor. Binswanger finds that for very low payoff levels, there exists a wide distribution in the levels of risk aversion. Nevertheless as payoffs increase in dollar value, the variance of this distribution decreases. Indeed, individuals become progressively more risk averse. Moreover he finds that wealth only slightly influences risk attitudes when payoff levels are low.

Binswanger's method represents one possible way of eliciting risk preferences. While this technique has its advantages in terms of simplicity, many new methods and game designs have since emerged. A second class of experimental games elicits *certainty equivalents* for individual lotteries. Kachelmeier and Shehata (1992) ask subjects to write down their minimum selling price for a series of proposed lotteries. These lotteries vary in terms of monetary prizes and win probabilities. A card with a numerical value is then randomly selected from a deck. Participants are paid the full value of the card if the amount is larger than the subjects' minimum selling price. Conversely participants will play the lottery if the amount on the card is less than their minimum selling price (Becker et al. 1964).[14] The authors establish that subjects are less risk seeking when monetary prizes increase (increasing relative risk aversion). Furthermore they demonstrate sensitivity to different win probabilities with the presence of a

[13] The other approach uses econometric methods to estimate individual risk aversion.

[14] For a more detailed account of how the values on the cards were constructed and how the lottery was plaid please refer to the article by Kachelmeier and Shehata (1992).

"downward curvilinear trend from highly risk seeing to risk neutral/averse preferences as the win percentages increase", which is partially consistent with Prospect Theory.

The main criticism with this form of elicitation is in the biases it implicitly creates. The way that the pricing task is framed (either in terms of willingness to pay or willingness to accept) can drastically affect risk preferences. Sellers tend to demand much higher prices than purchasers do (WTA>WTP), because they do not want to incur a loss (loss aversion). The low WTP prices reflect risk aversion in gains, and the high WTA prices represent risk neutrality or risk seeking in losses. As a result the experimental design creates bias, which leads to inconsistent estimates of individual risk aversion (Holt and Laury, 2006).

Holt and Laury (2006) develop a third type of experimental game that is most often used in the literature. The fundamental feature of this game is that it is based on pairwise lotteries. More specifically, subjects have to indicate their preference between Lottery A and Lottery B for a series of 10 paired lottery choices. The payoffs belonging to the first lottery (A) are less variable than the payoffs belonging to the second riskier alternative (B). Furthermore, the expected payoff difference is initially higher for the safe option (A). Nevertheless for subsequent lottery choices, the probability of winning the highest payout in the risky option (B) increases and the lottery produces a higher expected payoff. Subjects are asked to indicate the point at which they would switch from the safe Lottery A to the riskier Lottery B. The crossover point from A to B provides an estimate of subjects' coefficient of relative risk aversion. The game is played a maximum of 4 times with different *payoff conditions* (the initial low payoffs, hypothetical high stakes, real high stakes and a final round identical to the first). Contrary to the notion of constant relative risk aversion, the authors find that risk aversion increases as real payoffs are increased. Conversely they do not detect any significant changes in behavior when subjects are faced with higher hypothetical payoffs.[15]

[15] They conclude by presenting a "power-expo" function that permits the type of increasing relative risk aversion seen in the data.

B. Why has Expected Utility Theory Fallen out of favor? Alternative: Prospect Theory?

All of these experimental games are rooted in Expected Utility (EU) Theory. Nevertheless, there is mounting theoretical and empirical evidence suggesting that EU is not always the best framework to use when analyzing individual decision making under risk and uncertainty. The first major evidence against EU theory comes from the Allais Paradoxes, which includes a "common consequence" paradox and a "common ratio" paradox (Roth, 1995). The common consequence paradox demonstrates that individuals can make choices that produce indifference curves that are not always parallel. This violates the independence axiom. Similarly, the common ratio paradox suggests that individuals apply specific *weights* to the probabilities they face in pairwise lotteries.[16] This also violates the independence axiom.

The second major wave of criticism of EU comes from psychological evidence that subjects use procedures that are much simpler than EU expects when making their choices. Furthermore many researchers discovered that different forms of elicitations would yield different utility functions (please refer to Camerer's extensive review of individual decision making theory in Roth, 1995). Finally, in 1982 Machina compiled some evidence against EU, and came out with new tools for creating economic theory without the independence axiom.

One of the most widely accepted alternatives is known as Prospect Theory (PT), which is centered on three cognitive features (Kahneman and Tversky, 1979). First is the idea that individuals evaluate their options based on some underlying reference point. More specifically, this reference point is used to measure whether gains and/or losses are being incurred. In other words potential outcomes are defined in terms of *changes* of wealth (i.e. gains and losses) rather than in terms of *states* of wealth (i.e. total wealth). Framing outcomes in this way then affects how utility is measured.

Second is the principle of diminishing sensitivity, which applies to both gains and losses. This principle demonstrates that individuals are more sensitive to changes near their reference point than to changes that are further from it. It follows that for larger gains (further from the reference point), an

[16] Drezen Prelec (1998): "it refers to the observation that the more risky of two simple prospects becomes relatively more attractive when the probability of winning is reduced by equal proportion in both prospects"

individual is much less likely to take a risky gamble that may provide a higher payout, if they have a guarantee of receiving a slightly smaller amount. This notion of diminishing sensitivity can therefore explain risk averse behavior in terms of gains. To describe risk aversion within this framework, subjective utility is depicted as a *concave* function of money: a risky gamble is less attractive than the sure thing. Conversely, diminishing marginal sensitivity explains why individuals behave in a risk-loving fashion in terms of losses. Indeed people would rather select a gamble with a slightly larger loss that is merely probably, than incur a sure loss. To describe risk-seeking behavior within this framework, subjective utility is depicted as a *convex* function of money: a risky gamble is more attractive than the sure thing.

Third is the concept of loss aversion, which says that losses loom larger than gains. The intuition is that "a loss of X$ is more aversive than a gain of X$ is attractive" (Kahneman, 2011). Therefore in mixed gambles where both a gain and a loss are possible, loss aversion causes extremely risk averse choices. This can be seen on the utility function at the reference point. The slope of the utility function changes abruptly: the response to losses is much stronger than the response to gains.

Finally PT also incorporates a non-linear probability weighting function. The idea is that individuals attribute a decision weight to each outcome, which does not correspond linearly to the actual likelihood of the outcome (Wakker, 2010). More specifically individuals have a tendency to overweight low probabilities and underweight moderate and high probabilities. Overweighting of low probabilities leads to risk seeking behavior with improbable gains and risk averse behavior with unlikely losses.[17] Conversely underweighting large probabilities leads to risk aversion in gains and risk seeking in losses.[18] The weighting function also behaves inconsistently at the end points (moving from impossibility to

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[17] Example: Individuals choosing between 6$ or a 1% chance at 500 will tend to select the gamble because they overweight the probability of a 1% success rate.

[18] Example: Individuals choosing between 80$ or a 90% chance at 100$ will tend to select the certain option because they underweight the probability of a 90% success rate.

possibility, and possibility to certainty). This is because individuals place much higher weights on events that are judged to be either certain or impossible.[19]

There is a substantial amount of empirical evidence supporting PT over EU theory. Camerer (2001) compiled information on ten phenomena that were consistently detected across different types of field data. He demonstrates how these regularities can only be understood in the context of PT and not EU. For example, *loss aversion* can explain asymmetries in consumers' reactions to price increases and decreases. Similarly *risk-seeking behavior in losses* can explain why investors hold on to losing stocks for longer periods of time than they hang on to winning ones.[20] In summary, Camerer argues that PTs major appeal is in its ability to explain both the basic phenomena underlying EU, as well as the many anomalies that EU cannot account for.

Several experimental studies have also demonstrated that individual preferences do indeed depend on a *reference point* (a feature of PT not of EU). Kahneman, Knetsch and Thaler (1990) simulate market conditions by asking college students to trade goods amongst themselves. They detect what they term an "endowment effect". This refers to the idea that when a good becomes part of someone's endowment, he or she then perceives its sale as a loss. Sellers of a good will then demand a higher price than buyers, because losses are weighted more heavily than gains. The authors find that this manifestation of loss aversion can explain under-trading in certain markets.

List (2003) establishes the presence of an endowment effect when he studies real markets for two distinct goods. Moreover, he is also able to show that the endowment effect disappears (and subjects behave according to neoclassical theory), when individuals' market experience increases. Finally, Fehr and Goethe (1997) examine the behavior of workers in response to a fully anticipated wage increase. The authors find that total labor supply increases, while the effort levels decrease during each shift. The authors conclude that this phenomenon is most accurately explained via a target *reference* income model with *loss averse preferences*. Indeed workers earning higher wages will move above their reference

[19] This explains the attractiveness of lottery tickets (going from 0 to 1% chance at 1 million) and insurance policies (going from 98 to 100% coverage).
[20] For a full list of regularities that can only be explained by PT please refer to his paper.

target income and start experiencing decreasing marginal utility of income, which, in turn, will induce them towards providing less effort.

C. Experimental Games using Prospect Theory

There are only a handful of papers to date that have designed experimental games using prospect theory. The first paper by Tanaka, Camerer and Nguyen (2010) carefully constructs three series of pairwise lottery choices so that any combination of choices determines a particular set of prospect theory parameter values. These parameter values (risk aversion, loss aversion and nonlinear probability weighting) jointly determine the shape of the utility function. The authors run the experiment in Vietnam and successfully estimate each participant's parameter values. Tanaka, Camerer and Nguyen (2010) demonstrate that risk preferences are a function of age, education and income while loss depends heavily on income. Furthermore this particular game reduces to EU for certain parameter values. Nevertheless, given the data they collect, the authors are also able to reject the EU in favor of Prospect Theory. This game will be explained in greater detail in the following section.

Liu (2012) runs the exact same experiment in China and comes to very similar conclusions. She demonstrates that risk depends on gender and wealth while loss aversion is influenced by education and the degree of income diversification. She too finds that the EU model can be rejected in favor of PT.

This experimental game is used in the current paper as well. As a result we are one of the first papers to use prospect theory to measure farmers' risk preferences. Furthermore this is one of the first papers to use this measure of risk to establish whether or not risk preferences impact *willingness* to adopt a new technology (before diffusion actually takes place).

V. Contributions of the Current Paper

This paper draws from many different bodies of literature. The first set of papers that we examine follow an *ex-ante* approach and conduct their analysis before the technology is diffused within a community. They make use of SP methods to determine farmers' willingness to adopt a new technology, and to isolate the factors that would most likely increase adoption rates. The second set of papers follow an *ex-post* approach and collect their data after the technology has already been diffused. These studies base their analysis on observed behavior, and are able to identify various factors that are responsible for low adoption rates. Furthermore, some of these papers specifically choose to investigate the effect of risk preferences on the decision to adopt.

This paper is the first to use the *ex-ante* approach to specifically analyze the impact of risk preferences on farmers' willingness to adopt. We use a choice experiment to measure willingness to adopt, and a unique experimental risk game, rooted in prospect theory, to estimate farmers' risk preferences. As we have seen, there are a number of papers that use the *ex-ante* approach to understand technology adoption, but they all fail to include a measure of individual risk preferences. Similarly there are a number of studies that analyze the impact of risk preferences, but they all do so after the technology has been diffused.

As mentioned previously, the main benefit of our approach is that it allows us to provide third parties, namely scientists and implementing partners, with valuable information that can be used to increase adoption rates. More specifically, by determining whether risk preferences affect farmers' willingness to adopt, implementing partners can either choose to invest in risk coping mechanisms before diffusion takes place or not.

Section IV: Design of the Study and Descriptive Statistics

I. Main Goal of the Survey Procedure

This paper seeks to identify the main factors affecting the probability that Colombian farmers will adopt a new technology similar to the push-pull technique by Poveda and Gómez (2009). More specifically, we investigate whether higher levels of risk aversion will reduce farmers' initial willingness to adopt, and the *extent* to which they will adopt the new technology. In order to answer these research questions, a detailed data collection process took place during the summer months from June to August 2012.

The survey process was designed with two specific goals in mind. The first was to obtain a precise measure of farmers' willingness to adopt a new technology. To this end, we constructed two-stated preference games, a choice experiment (CE) and a contingent valuation (CV) question, in order to estimate the probability that each farmer would adopt, and the extent to which they would adopt the new technology.

The second objective was to collect data on every potential barrier to adoption. These barriers can be categorized into two groups: attributes of the new technology and characteristics of the farmer. Indeed the farmer first bases his or her decision to adopt on the features of the new technology. If certain characteristics of the new technique are unappealing to the farmer, he or she may choose not to adopt. For example, if the technology is labor intensive and the farmer is averse to supplying more labor, then he or she may decide not to try it. As a result, it is important to understand farmers' preferences towards these various attributes. The CE was used to successfully estimate farmers' attitudes towards four specific features of the new technology. Secondly, the farmer's decision will also depend on his or her wealth, age, education, risk preferences and other social factors. A questionnaire and an experimental game were constructed in order to obtain the necessary information.

II. The Survey Procedure

The objective of the study is to identify the potential barriers to adoption for potato farmers in Colombia, with a specific emphasis on the impact of risk preferences on adoption decisions. To this end we collected data from 184 farmers in six different villages in the Department of Cundinamarca, Colombia. The data collection process was conducted in partnership with the National Potato Growers' Federation known as FEDEPAPA during the months of July and August 2012.

FEDEPAPA is a privately run institution that focuses on capacity building and training initiatives among Colombian potato growers. Their highly qualified team of agronomists visits farmers on a monthly basis in order to assess the health of the farmers' crops, and diagnose any pest or fungal problems that may have damaged the plant. The agronomists then make specific recommendations to the farmers that help ensure healthier crop development and higher yields. The association also organizes weekly and monthly general assemblies, inviting farmers to share their experiences and their concerns. These meetings also provide a platform for FEDEPAPA to teach best practices and introduce new techniques in the domain of potato farming. Finally, FEDEPAPA runs a number of independent agro-chemical stores that sell a wide range of useful products to farmers. The staff is well trained, and provides valuable advice to the farmers when they make their purchases.

The data collection process was conducted in two specific regions of Colombia. These locations were selected with the help of our collaborators at FEDEPAPA. The first area is located to the North East of Bogota and the second lies to the south of the capital. These regions are known for producing high quantities of potatoes. Surveys were administered in nine villages from the first northern region and 4 villages from the second southern region. We elected these particular villages for two main reasons. Firstly they were easily accessible from Bogota. The furthest village was approximately two hours away by car. Secondly FEDEPAPA operated within each one of these villages and had established direct ties with the community of potato farmers.

At the very beginning of June, the research team met with the agronomists from FEDEPAPA that worked in the villages of interest. We explained to them the purpose of the project, and reviewed our expectations in terms of the data collection process. These agronomists provided valuable suggestions and became instrumental to the project's successful implementation in the field. They first began by notifying the farmers about the study a few weeks before data collection was scheduled to take place. A second reminder was also sent out a few days before the team of interviewers was scheduled to arrive. The agronomists would generally coordinate with the village head to ensure that 10-20 farmers would show up for the interviews. The agronomists made it very clear that we were an independent research group trying to gain a better understanding of the challenges farmers face, and a better sense of their preferences for different types of technologies.

The data collection process was organized largely the same way within each village. A research group consisting of the five to eight enumerators would travel by car to the village alongside an agronomist from FEDEPAPA. The surveys were generally conducted in a public building (school or community center) and lasted the better part of the morning. Farmers were invited to come at 9:00 am and the activities would begin at 9:30 am with a brief presentation about the purpose of the project. We emphasized many times over that we were an independent research group, and that any information provided to the enumerators would remain confidential.

The sessions were broken up into two sections. The first section was a one-on-one interview with an enumerator and lasted approximately one hour. The second section was a group activity and took an additional hour to complete. Once the farmers finished both sections, a complementary lunch was served. The farmers also received one third of a day's wage on average.

The first section consisted of two stated preference activities (a CE and a CV question) and a separate questionnaire. The CE asked farmers to choose between the status quo technology they currently use and a series of alternative technologies that differed based on yield, health risk, cost and work load. This activity was used to estimate farmers' willingness to adopt. It also served to gather information on the first barrier of adoption: attributes of the new technology. The contingent valuation question asked farmers how much land they would be willing to rent to a University such as Cornell that wanted to test the effectiveness of a new pesticide free technology on a parcel of their land. This question was framed specifically to measure the extent to which farmers were willing to adopt. Finally, the questionnaire, which took 40 minutes to complete, asked farmers about household characteristics and farming practices. As mentioned previously this questionnaire was designed to collect information on the second potential barrier to adoption, namely farmer characteristics.

The second section brought farmers together to play an experimental game. This game, borrowed from Tanaka, Camerer and Nguyen (2010), was designed to measure farmers' risk preferences. Indeed, a farmer's attitude towards risk constitutes another potential barrier to adoption. Those who are more risk averse may decide that they do not want to try a new, and unfamiliar, technology. The game, detailed below, took approximately 30 minutes to explain and 30 minutes to play. It asked farmers to choose between three series of pairwise lotteries. Farmers played for real money.

III. Experimental Design: Choice Experiment, Contingent Valuation and Risk Game

The following section provides a detailed description of the four different survey instruments we use to collect the necessary data. We first present how we construct the CE and CV question in order to measure farmers' willingness to adopt and extent of adoption. The CE also provides information on farmers' attitudes towards the first barrier to adoption, namely the features of the new technology. Then we describe the two tools we use to gather information on farmers' personal characteristics, which constitute the second barrier to adoption. This includes both a questionnaire and an experimental game.

A. Measuring Willingness to Adopt and Extent of Adoption

The literature identifies two decisions that farmers must make when faced with a new technology. Firstly, the farmer needs to elect whether or not they will adopt the new technology. Secondly, the adopters must decide how many acres of their land they will devote to the new technology. These two decisions are generally related. The factors that encourage adoption tend to be the same as those that incite farmers to devote more of their land to the new technology.

These two decisions can be observed after the technology is diffused. They can also be inferred beforehand by assessing farmers' hypothetical choices under certain specific scenarios, which are carefully designed by the researcher. The former has been done extensively in the literature while the later remains underutilized. The advantage of the "ex-ante" approach is that it allows economists to gather valuable information about the factors that will encourage and impede adoption. Indeed, it reveals which factors are most likely to affect the probability of adopting in the future. This information is then be provided to scientists who can alter the technology accordingly, as well as to policy makers who can attempt to address farmers concerns before diffusion takes place.

i. The Choice Experiment: Willingness to Adopt

The first decision about whether or not to adopt is modeled using a choice experiment. We use this approach because it allows us to simultaneously measure farmers' willingness to adopt a new technology, and their attitudes towards different attributes that a new technology might possess. This is particularly important for this study because we hypothesize that the features of a new technology constitute one potential barrier to adoption. Furthermore, the choice experiment is useful from a practical perspective. Indeed the technology developed by Poveda and Gómez (2009) was not yet finalized when the survey was being administered. As a result we deemed it more appropriate to measure farmers' attitudes towards technologies that differed based on certain attributes.

We ask farmers to choose between two different technologies for dealing with the Guatemalan potato moth. These technologies differ based on four specific attributes: yield, labor requirements, cost and health/environmental impact. We successfully determined that these four attributes would have the largest impact on farmers' decisions to adopt. This was established after multiple discussions with the agronomists from FEDEPAPA and the farmers themselves. Furthermore, we wanted to keep the number of attributes as low as possible so that farmers would not get lost in the descriptions of each technology. The choice experiment exercise was pre-tested, and respondents were asked about their understanding of the terms and whether they felt they could meaningfully evaluate the different technologies based on the attributes we had selected.

Each choice set pits a single technology against the current technology (status quo). This design is selected for four reasons. Firstly, the CE is made more realistic by including the status quo. Indeed, when making their decisions, farmers always have the option to maintain current practices. Secondly, having two or more non-status quo options decreases efficiency because we need to consider all possible combinations (and correlations) between the levels of attributes of the two alternative options. Thirdly, it also hurts the theoretical properties of the elicitation mechanism. In a recent paper, Vossler et al. (2010) restricted their analysis to a binary CE, which asked participants to select between one public project and the status quo. They argue, along with Carson and Groves (2007), that choice experiments including more than three alternatives must satisfy many more assumption in order for incentive compatibility to hold. Finally, it allows us to address the idea that risk aversion might influence the decision to adopt. Indeed it is often the case that respondents prefer the status quo because they do not want to take a risk with something new. This particular elicitation mechanism lends itself to an identification of risk aversion.

We then carefully select the various levels that each attribute can take. We first determine the baseline levels from FEDEPAPA's records on the average yield, cost, labor requirements and health impact of the status quo technology. Average yield is approximately 250 cargas per hectare per harvest and average cost is 375,000 Colombian pesos per hectare for a single harvest.[21] We define labor requirements and environmental impact qualitatively. The baseline amount of labor is "Same amount of labor as the status quo" while the baseline environmental/ health impact is "negative impact on health/ the environment". We decide to use qualitative descriptions instead of quantitative ones because the farmers often describe the health impact of a technology, or the labor it requires, in qualitative terms.

[21] One US dollar is equal to 1,800 Colombian pesos. Therefore 375,000 Colombian pesos is approximately 205 US dollars. Furthermore one "carga" is equal to 100 kilograms. Therefore 250 cargas is approximately equal to 25,000 kilograms.

During the pre-test we tried to quantify health/environmental impacts and labor requirements using numerical values, but the farmers quickly indicated that this was confusing and misleading.

We then select one or two additional levels that each attribute can take, which differ from the baseline values. The different levels have to satisfy three criteria. Firstly, they need to resemble potential values that the new push-pull technology might require/produce. Indeed the goal of the study is to determine whether or not farmers are interested in new technologies similar to the one being developed by Poveda and Gómez. Secondly the levels need to straddle the baseline values. It is important to have upper and lower bounds for each attribute, so we can observe how farmers react to positive and negative changes in the attribute. Finally, we avoid selecting extreme levels for each attribute. We re able to use FEDEPAPA's yearly records, which document changes in yield and cost, to ensure that our chosen levels are appropriate and not too extreme. Indeed, selecting extreme levels would have meant presenting farmers with new technologies that demanded drastic changes in current practices. This is unappealing because farmers are unlikely to adopt these types of technologies under any circumstances. Moreover, Hensher et al. (2005) and Carson and Groves (2007) argue that subjects might not be able to relate to alternatives that differ substantially from the status quo.

As a result, the attributes 'cost' and 'yield' are given 3 different numerical values. The labor requirements are also assigned three levels but they are qualitative in nature. The technology will either require the "Same amount of Labour", "More Labour" or "Less Labour" than the status quo. Finally two levels are selected for the environmental/health factor. These were either: "negative environmental/ health impact" or "positive environmental/ health impact".

In this study we use a fractional instead of a complete factorial design, even though the latter presents a greater number of statistical advantages. Indeed, the complete factorial guarantees that all attribute effects of interest are truly independent (Louviere et al., 2000). While this is very attractive, in this study the full factorial would have required 3x3x3x2=54 different choice sets. It would have been impossible to present each farmer with the full set of choices. Therefore we reduce the total number of unique sets by generating a fractional factorial design. More specifically we use an orthogonal array, in which all estimable main effects are uncorrelated. To this end we employ the SAS macro %mktex, which produces an optimal design that is both orthogonal and balanced, and therefore also has maximum efficiency (Kuhfeld, 2010). This produces 18 unique choice sets and the resulting *D*-efficiency, A-efficiency and G-efficiency are all 100 percent.[22] Furthermore all canonical correlations on the diagonal are zero, which tells us that the design is orthogonal i.e., that every factor is uncorrelated with every other factor (Kuhfeld 1994, 2010). Finally the design has perfect balance, which means that each level occurs equally often within each factor, and the intercept is orthogonal to each effect.

We determine that it would still be too time consuming to present each farmer with 18 choice sets. Therefore these 18 choice sets are further split into two blocks and participants are randomly assigned one of the two blocks in the experiment. As a result exactly half the subjects receive the first block and the other half receive the second. Table 1 illustrates how the two technologies were presented to farmers. Please refer to the Appendix 2 for the entire CE as it was presented to farmers.

	Technology A (Status Quo)	**Technology B (Alternative)**
Average Yield	270 cargas/hectare	270 cargas/hectare
Labor Requirements	Same amount of labor	More labor
Cost	375,000 pesos	450,000 pesos
Health/ Environmental Impact	High probability of developing an illness	Low probability of developing an illness
I choose: (mark with an X)		

Table 1: Choice Experiment (One Choice Set out of Nine)

The Choice Experiment was administered along with the questionnaire. Farmers went through each choice set with the enumerator, who would stress the importance of answering truthfully. It was critical that farmers understand that any information they provided would be passed along to scientists, who could then devise more appropriate technologies. Indeed, previous research by Vossler et al. (2010), and Carson and Groves (2007) finds that discrete choice experiments are incentive compatible when

[22] A-efficiency is a function of the arithmetic mean of the eigenvalues of $(X'X)^{-1}$. D-efficiency is a function of the geometric mean of the eigenvalues of $(X'X)^{-1}$, G-efficiency, is based on, the maximum standard error for prediction over the candidate set.

subjects believe their answers will have an impact on future policy outcomes. This condition is known as consequentiality.

Finally, we examine the set of choices farmers make in a random utility framework. The choices are assumed to be independent. They are based on the utility that the farmer derives from each technology in a set of two alternatives: a new technology and the status quo. The full model will be detailed below in the following section. Nevertheless it is worth mentioning that it successfully allows us to determine which attributes of the new technology (e.g. more yield or less labor) increase the probability that a farmer adopts.

ii. The Contingent Valuation Question: Extent of Adoption

The second main objective is to establish the extent to which farmers are willing to adopt the new technology. To this end, we design a one-and-a-half bound model for the discrete choice contingent valuation method. We ask farmers whether or not they would be willing to rent a parcel of their land at a proposed price to a team of scientists from Cornell University. We explain that the scientists will be using the land for an entire cropping season (4-6 months) in order to test the effectiveness of a new pesticide free technology on the potato crop. If farmers are willing to accept the dollar amount, they are also asked to disclose the amount of land they would be willing to rent at that price. While the scientists only *need* ¼ of a hectare, more land is always better in order to test the efficiency of the product on larger parcels. We use farmers' answer to this second question as a proxy for the amount of land farmers intend to devote to a new technology. Indeed, if farmers instinctively devote more land to a trial then we assume they would also allocate more land to a new technology if it were offered. Therefore we use this as our measure of extent of adoption, given that farmers have expressed a desire to adopt.

We choose to use a CV instead of a CE to investigate the extent of adoption for practical reasons. If we had used the CE, we would have had to ask farmers if they were willing to rent their land for each one of the new technologies being offered, and how much land they would rent at the agreed upon price. This would have been very time consuming. Moreover it may have confused the farmer who would likely have answered similarly after each choice set was presented. Therefore the CV question is deemed more appropriate.

Furthermore, we could have chosen to frame the CV question as a "willingness to accept" or "willingness to pay" question. We choose the former for two reasons. Firstly, local agronomists had indicated to us that farmers would only try a new, pesticide free, technology if they were given some financial incentive to do so. This idea of using incentive payment programs to encourage the use of new environmentally friendly practices is not new. In 1990 USDA initiated the Water Quality Incentive Program that supplied technical assistance and monetary payments to farmers who agreed to implement better agricultural practices. Cooper and Keim (1996) then used a WTA measure in order to determine the exact amount the program would need to pay out in order to entice farmers to adopt these new practices. Secondly, we choose to use a WTA question because previous research discourages the use of WTP measures when dealing with private goods. Carson and Groves (2007) argue that subjects have an incentive to behave strategically and answer, "yes" to such questions. A "yes" response encourages the production of the good and lets the agent decide later whether or not to purchase it. Conversely, in the WTA game we designed, there are no obvious incentives to answer in the affirmative and then to rent out more land.

There are many ways we could have worded the specific WTA question for the purposes of this study. The most straight forward method would have been to follow Cooper and Keim (1996) and ask farmers how much money they would be willing to accept in exchange for adopting the new technology. The problem with this approach is that we are not working with a specific technology in mind. While the entomologists at Cornell were in the process of developing a new push pull technique, they were still running the final tests at the time of the study. Moreover, we do not want implement the game using a fictitious technology. Therefore we decide to frame the question as the amount of land farmers are willing to rent to an institution that wants to test the efficiency of a new technology. We deem this to be a good proxy for the amount of land farmers will agree to allocate to a new technology, should it become available.

Finally we choose to use a one-and-a-half bound approach (OOHB) rather than a single (SB) or double bounded (DB) method. Most of the literature uses the DB approach because the estimates it produces are more efficient than the estimates derived from an SB. Hanemann and Kanninen (1991) demonstrate this property both analytically and empirically. Nevertheless there is mounting evidence against the DB model as studies have found the subjects' answer to the second price is often inconsistent with their answer to the first.[23] As a result we opt for the OOHB model, which Hanemann et al. (2001) test analytically and empirically. They find that the move from SB to OOHB captures two thirds of the gains in efficiency associated with moving from SB to DB. Moreover they find that the OOHB estimates are consistent while the DB estimates may not be.

Before moving on to the next phase of the data collection process, it is worth mentioning that the CV could also have been used instead of the CE to identify the factors that impact adoption (i.e. the first decision farmers must make when they are faced with a new technology). Nevertheless we choose to use the CE for a number of reasons. Firstly, the CV question asks farmers whether or not they are willing to rent a parcel of their land to an institution for experimental trials. We believe that a farmer's willingness to rent out their land is a less precise proxy for their decision to adopt a new technology. Secondly, the CE boasts many statistical advantages, and also allows us to determine which attributes of the new technology farmers find most attractive. The full extent of these advantages was reviewed in the literature review.

B. Measuring Barriers to Adoption

The choice experiment and the contingent valuation method successfully provide measures of farmers' willingness to adopt, and extent of adoption. Furthermore, the choice experiment has the added benefit of supplying valuable information on the first potential barrier to adoption: attributes of the given technology. Indeed farmers' responses to the choice experiment demonstrate how changes in attribute levels impact the probability of adopting.

[23] Hanemman (1991), McFadden and Leonard (1993), Cameron and Quiggin (1994), Kanninen (1995), Herriges and Shogren 1996), DeShazo (2000)

Next we collect information on the second main barrier to adoption: the social characteristics of the farmers. This includes features such as wealth, education, age and risk among others. The measurement of risk is detailed in the following section, as it required a separate experimental design.

i. Survey: Personal Characteristics

The information on social attributes is collected primarily through the use of a questionnaire, which includes five main sections. The sections cover family demographics, farming characteristics, household finances (income, saving and credit), household shocks, and social networks. Please refer to Appendix 1 to see a copy of the questionnaire that was used to collect this information.

While we ask a large number of questions, we are most interested in farmers' levels of education, age, gender, relationship to household head, total farm size, access to social networks and wealth. We simply ask farmers their age, gender, education, farm size and relationship to household head. Moreover, we use a contemporaneous measure for social networks: do you take advice from other farmers and/ or extension agents? This is the most accurate depiction of social networks that we could achieve without a panel data set.

We also determine that ownership of durable goods is a good proxy for wealth. While we were hoping to be able to use family income, it proved to be very difficult to obtain a precise measure for two reasons. Firstly, many Colombian potato farmers do not keep exact records of sales and expenditures. Therefore, they cannot be sure of how much they make in any given year. Secondly, some farmers do not want to draw any attention, and drastically understate their yearly earnings. Indeed, they are hesitant to reply truthfully because they fear this information will be leaked to the government, who could then charge them higher taxes. We also consider using savings, loans or expenditures as proxies, but these prove to be problematic as well. Firstly, we find that most Colombian farmers do not accumulate savings. The money that is left over after a harvest is almost always reinvested in cattle or farm assets. While we try to quantify these amounts we are not often successful, as farmers will dramatically understated the amount. Secondly, we find that the size of the loans taken by a household do not correlate with their wealth. Many well off households take out very large loans to sustain the high levels of agricultural production on their farms. Conversely some very poor households also have to take out large loans in order to cover their expenses. Finally, we cannot use family expenditures because most of our subjects are males, and do not have a good sense of how much their wives spend on different household items.

Our proxy for wealth is carefully calculated for each individual farmer. We present farmers with a list of ten different durable goods and ask them to indicate which ones they own. This list includes: cars, motorcycles, bicycles, radios, televisions, washers, refrigerators, computers or cameras, tractors and large machinery. Farmers are also asked to provide a dollar amount for each of asset they owned. The variable for wealth is then calculated by summing up the dollar value of all the farmer's assets.

The following table (Table 2) provides the summary statistics for these key variables of interest and a few additional ones. These supplementary statistics are important as well because they help to paint a more detailed picture of the local farming community we are working with.

On average, the interviewee is forty-two years old and belongs to a household with three other members. The majority of farmers we interview are also male with primary levels of education (approximately seven years). Furthermore, most of the interviewees are heads of household. Indeed, 70% of respondents identified their household status as "head of household". The remaining 30% are evenly split between spouses and sons/daughters of the household head. Finally, farmers' level of wealth varies greatly within this sample. The median level of wealth (as measured by the total value of farmers' durable goods) is approximately 1,800 American dollars while the mean is $5,000. Moreover, the interquartile range shows that wealth fluctuates between $500 for the poorest households and $9,000 for the richest.

Additionally, the majority (almost 80%) of farmers who participate in the study have devoted their entire lives to agriculture and farming potatoes. Most are either members of FEDEPAPA, or informally consult the association about their crops. More specifically, approximately 75% of farmers report a membership status, while 82% have received advice from FEPEPAPA in some capacity over the last 6 months. Only 8% of the sample does not interact with FEDEPAPA at all. Furthermore, many farmers have developed strong relationships with their peers. Approximately 68% receive some advice from other farmers in the last six months.

In Colombia most of the land surrounding Bogota is privatized and farmers either own their own land, or they rent land, or they do some combination of both. Approximately 36% of the farmers in the sample own the plots they farm, while 13% rent land from others and 45% own some of the land they farm and rent the rest from others. The remaining 6% of the sample own their land in partnership (usually in the form of a cooperative). The average household owns approximately 10.88 hectares of land. This value is large and is likely slightly skewed by some of the very large farms in our sample. Indeed, the median household owns approximately 5 hectares of land. Furthermore most households only cultivate the potato crop. Approximately 62% of farmers only plant potatoes, while the remaining 38% cultivate a second or third type of crop. However they rarely devote more than one or two hectares of land to the secondary crop, which is mainly harvested for the household's private consumption. The secondary crop is generally another tuber, onion, carrot or peas. Finally, the majority of farmers also raise cattle and/or chickens on their land. Approximately 81% own some form of livestock (primarily cows). Many of the famers expressed a strong desire to move away from potato farming and invest more heavily in livestock. This is attributable to the growing number of pests that plague the potato. They also consider the livestock business to be a safer investment strategy.

Table 2: Summary Statistics of Colombian Potato Farmers interviewed around Bogota, Colombia

VARIABLES	Mean	25%	Median	75%
Household Size	4.41	3	4	5
Age	42.5	31.5	42	54
Wealth (Proxy- Millions of Pesos)	9.23	0.8	3.25	16.55
Education	8.63	7	7	12
Total Farm size in hectares	10.88	3	5.85	10.41
Livestock*	0.81	-	-	-
Gender*	0.83	-	-	-
Head of Household (Yes or No)*	0.69	-	-	-
Own Land*	0.36	-	-	-
Rent Land*	0.13	-	-	-
Own and Rent Land*	0.45	-	-	-
Own Land in Partnership*	0.06	-	-	-
Member of FEDEPAPA*	0.75	-	-	-
Advice FEDEPAPA*	0.83	-	-	-
Advice from Other Farmers*	0.68	-	-	-

**The variables marked with a * are binary (0=No and 1=Yes) and hence do not have an interquartile range that can be interpreted. We leave them blank.*

ii. Experimental Game: Risk Preferences

Reasons for Selecting This Game

The survey is instrumental for collecting data on farmer characteristics such as wealth, farm size, and education, among others. Nonetheless we also need to make use of an experimental game in order to estimate farmers' risk preferences, which can also impact the decision to adopt.

We use the experimental game designed by Tanaka, Camerer and Nguyen (2010) because of its three major advantages. Firstly it is structured based on prospect theory and reduces to EU under certain conditions. So while the game is designed to elicit three prospect theory parameters (risk aversion, loss aversion, and nonlinear probability weighting), it also supports EU if certain conditions hold. The use of prospect theory is also better suited to answering our question of interest regarding technology adoption. Indeed farmers may choose not to adopt a new technology because they are extremely loss averse and they do not wish to take on any additional risks. Their desire to maintain the status quo technology stems from this extreme aversion to loss. This is also known as the status quo bias and can be readily addressed using Prospect theory (Kahneman et al. 1990).

Secondly, this design was successfully implemented in Vietnam (Tanaka, Camerer and Nguyen, 2010) and China (Liu, 2012) where education levels are comparable to Colombia's. The game is fairly accessible to farmers with primary education, provided the researchers offer a comprehensive explanation. Thirdly, the game uses real payouts with non-negligible sums. The fact that subjects are playing for real, and potentially sizeable amounts, encourages them to take an interest in the game and answer truthfully. Their responses to this experimental game can then be used to predict attitudes towards "real world" risks. This idea that experimental games should involve real gambles for large stakes is well supported by the literature. Indeed, several papers have compared the outcomes from using real versus hypothetical gambles. The majority of these studies find that real payouts induce subjects to behave in a more risk averse fashion.[24] Furthermore the literature argues in favor of high payouts. Kahneman and Tversky (1979) maintain that small stakes games restrict their generality because people tend to behave in a risk neutral manner. Furthermore Holt and Laury (2000) provide conclusive evidence that high payouts with larger stakes are more effective than high payouts with lower stakes. They demonstrate that subjects facing hypothetical choices have a hard time predicting how they would behave under high payoff conditions. They find that subjects risk preferences change significantly in the face of real high payoffs but not hypothetical high payoffs.

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[24] Edwards, 1953; Becker DeGroot and Marschak, 1963; Camerer ,1985; Camerer, 1995; Battalio, Kagen and Jirnayakul, 1990; Hogarth and Einhorn, 1990; Shoemaker, 1990; Slovic, 1969

We follow Tanaka Camerer and Nguyen (2010) and use a utility function given by cumulative prospect theory with a one-parameter form of Drazen Prelec (1998)'s axiomatically derived weighting function. It can be written as follows:

For x>y>0 or x<y<0 (Gains OR Losses)	For x<0<y (Gains AND Losses)
$U(x,p;y,q) = v(y) + \pi(p)(v(x) - v(y))$	$U(x,p;y,q) = \pi(p)v(x) + \pi(q)v(y)$
Where $v(x) = \begin{cases} x^{\sigma} & \\ -\lambda(-x^{\sigma}) & \text{for x<0 only} \end{cases}$ $\pi(p) = \exp[-(-\ln p)^{\alpha}]$	

The utility function is constructed based on simple prospects of the form (x, p; y, q). In such a formulation one receives x with probability p, y with probability q, and nothing with probability *1-p-q* (Kahneman and Tversky 1974). *U (x, p; y, q)* represents the expected prospect *value*. The value of each prospect depends on two parameters: π and v. The first parameter π assigns a decision weight $\pi(p)$ and $q(p)$ to each probability (p) and (q). This reflects the impact of each probability p and q on the overall value of the prospect. The second parameter, v, assigns a subjective value (a number) to each outcome. This value function depends on two parameters σ and λ. More specifically, σ represents the concavity of the value function, which reflects a subject's aversion or preference for risk. Meanwhile, λ dictates the curvature of the utility function below zero relative to the curvature above zero and represents a subject's degree of loss aversion (Liu 2012). When $\lambda \neq 1$, there is kink in the indifference curve around zero. Moreover a higher λ, indicates that the subject is more loss averse.

Finally, we follow Tanaka Camerer and Nguyen (2010) and use Prelec's probability weighting function $\pi(p)$, which depends on α. If $\alpha<1$ then the function has an inverted S shape, which demonstrates that individuals overweight small probabilities and underweight large probabilities (as predicted by Khaneman and Tversky, 1979). Conversely if $\alpha>1$ then the weighting function has an S shape, which illustrates that individuals overweight small probabilities and underweight large probabilities.

Procedure for Experimental Game

Each participant is invited to play the risk game after completing the questionnaire. Participants are generally assembled into groups of eight players with two enumerators leading the discussion and explaining the rules of the game. Each subject is handed three sheets of paper corresponding to the three independent series of the game, which together comprise 35 pair wise lotteries. Subjects are instructed to keep their answers to themselves and not to look at their neighbors' sheet. This specific instruction is repeated multiple times and on the rare occasion that the players still try to "cheat", the enumerators will stand by that player and make sure the neighbors' answers are shielded.

The three series of pair-wise lotteries consist of 14, 14 and 7 rows respectively. Each row contains two different lotteries: Cartagena or Bogota. In order to make the game more realistic and comprehensible to the players, the lotteries are assigned the names of two major cities in Colombia (Cartagena and Bogota). Each enumerator then plays the role of a salesperson offering participants the chance to buy the lottery ticket from the city they represent. Furthermore, to make the situation more tangible each new row is introduced as a new day of the week. Please refer to Appendix 3 for an example of how these lotteries were displayed to farmers.

The participants are asked to choose between the lottery from Bogota and the lottery from Cartagena for each row of the series. As we will see below, the lottery from Bogota is inherently riskier.

Indeed, while there is a larger prize to be won from choosing Bogota, the chance of winning that prize is fairly small.

The payoff matrix below corresponds to the first row of the first series. It was also the row used to explain the concepts of the games to the players.

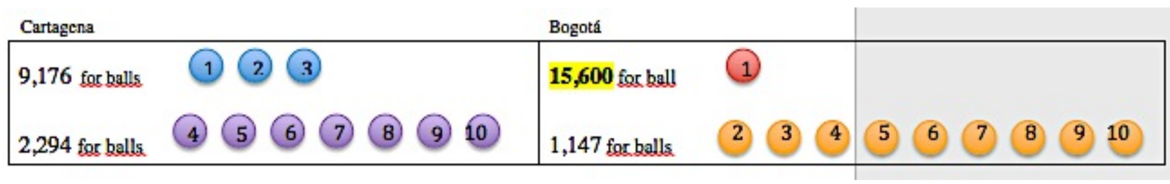

Figure 4: Payoff Matrix for the First Row of Series 1 in the Experimental Risk Game

The explanation of the previous matrix requires that a bingo cage with 10 balls be on display. Each ball within the cage has a number from 1 to 10 on it (which correspond to the 10 balls that are visible in the payoff matrix above). The balls are passed around the group to prove to the subjects that each ball only appears once. The enumerators explain that if ball 1 is drawn from the cage and the participant chooses the lottery from Bogota, they will win 15,600 pesos (roughly half a day's wage). Conversely, if they select the lottery from Cartagena they will only win 9,176 (roughly a third of a day's wage). As a result Cartagena's lottery provides a 30% chance of winning 9, 176 pesos and a 70% chance of winning 2,294 pesos. On the other hand, Bogota's lottery provides a 10% chance of winning 15,600 pesos and a 90% chance of wining 1,147 pesos.

Each subsequent row presents these two lottery choices with slightly different payoffs. More specifically, in Series 1 and 2, the lottery from Cartagena stays the same in expected value while the lottery from Bogota increases in expected value. Initially, the expected value of the lottery from Cartagena exceeds the expected value associated with the lottery from Bogota. Nevertheless, by row seven in Series 1, and row 1 in Series 2, the reverse is true, and the lottery from Bogota has the higher expected value. An expected-value maximizer should switch from Cartagena to Bogota in the seventh row of Series 1, and in the first row of Series 2. The later a subject decides to switch over to Bogota, the more risk averse he or she is.

In Series 3 we are dealing with gains and losses. This time the payoffs associated with both lotteries change. More specifically, the losses associated with Cartagena increase as we move down the rows and the losses associated with Bogota decrease. The expected value of Bogota's lottery exceeds that of Cartagena's by the second row. The later a subject decides to switch the more loss averse they are.

The game officially begins once all the explanations are provided. This generally takes 20 to 30 minutes. As a group we then proceed with each one of the three series of pairwise lotteries. The farmers are asked to indicate which lottery ticket they prefer for each individual row of the series. Monotonic switching is enforced: subjects who switched over to the riskier lottery in Bogota are no longer allowed to select the lottery from Cartagena. Nevertheless, each series is independent and, as a result, if players choose to switch to Bogota in Series 1, they can start over with Cartagena in Series 2. Subjects can also choose to never switch, or to switch right away in row 1 of each series.

Due to monetary constraints, not every row can be played for real money. Subjects are warned at the beginning of the game that they will randomly select a day to be played for real money. The enumerator will go around with a bag containing 35 balls, each one corresponding to a unique row of the game. The farmers will then each select one ball that indicates which game they will play for real. For example: suppose a subject chooses Bogota for the first row of Series 1 and the first row of Series one (Monday) is selected for actual payment. Then if the number 1 ball is drawn from the bingo cage, the player will win 15,600 pesos. However if balls 2-10 are drawn they will only win 1,147.

The payoffs in Series 1 and 2 are strictly positive while the payoffs in Series 3 are made to be both positive and negative. As a result, it is theoretically possible to lose money in the game. Nevertheless it would have been unethical to take money away from our subjects. Therefore, at the beginning of each game, we announce that we will be compensating farmers for their participation in the study. Any losses they might incur in the game will simply be deducted from this fixed amount. In the end the average payoff was approximately 10,000 pesos or, equivalently, one third of a day's wage. This highest possible payoff was 390,000 Colombian pesos, or $215.

Estimation of Parameters

Tanaka Camerer and Nguyen (2010) construct their game so that "any combination of choices in the three series determines a particular interval of prospect theory parameter values" (Tanaka, Camerer and Nguyen, 2010). In particular, the switching points in Series 1 and Series 2 are used to find the curvature of the utility function, σ, and the nonlinear probability weighting parameter α. The estimate of σ is then used along with the switching point in Series 3 to determine the loss aversion parameter λ. The following Table 3, *borrowed from* Tanaka Camerer and Nguyen (2010), clearly demonstrates that each combination of switching points from the three series produces a unique set of values for σ, α and λ.

Series One Questions

σ\α	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.2	9	10	11	12	13	14	Never
0.3	8	9	10	11	12	13	14
0.4	7	8	9	10	11	12	13
0.5	6	7	8	9	10	11	12
0.6	5	6	7	8	9	10	11
0.7	4	5	6	7	8	9	10
0.8	3	4	5	6	7	8	9
0.9	2	3	4	5	6	7	8
1.0	1	2	3	4	5	6	7

Series Two Questions

σ\α	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.2	Never	14	13	12	11	10	9
0.3	14	13	12	11	10	9	8
0.4	13	12	11	10	9	8	7
0.5	12	11	10	9	8	7	6
0.6	11	10	9	8	7	6	5
0.7	10	9	8	7	6	5	4
0.8	9	8	7	6	5	4	3
0.9	8	7	6	5	4	3	2
1.0	7	6	5	4	3	2	1

Series 3 Questions

	σ=0.2	σ=0.4	σ=0.6	σ=0.8
1	λ>0.14	λ>0.17	λ>0.20	λ>0.25
2	0.14<λ<1.26	0.17<λ<1.32	0.20<λ<1.38	0.25<λ<1.45
3	1.26<λ<1.88	1.32<λ<1.77	1.38<λ<1.71	1.45<λ<1.69
4	1.88<λ<2.31	1.77<λ<2.25	1.71<λ<2.25	1.69<λ<2.30
5	2.31<λ<4.32	2.25<λ<3.95	2.25<λ<3.73	2.30<λ<3.63
6	4.32<λ<5.43	3.95<λ<5.03	3.73<λ<4.82	3.63<λ<4.76
7	5.43<λ<9.78	5.03<λ<9.29	4.82<λ<9.14	4.76<λ<9.27

Table 3: Switching Points and Approximations for σ, α and λ: Tanaka, Camerer and Nguyen (2010)

The values in this table are derived using different sets of inequalities, which are constructed from the switching points in each one of the three series. The following paragraph explains how these inequalities are created. To begin, if a farmer switches at question N, we assume they preferred lottery Cartagena to lottery Bogota in the N-1th row, and Bogota to Cartagena in the Nth row. We can then infer that they derive a higher expected utility from Cartagena (U^C) in the N-1th row, and from Bogota (U^B) in the Nth row. A concrete example provides further insight. If a subject chooses to switch at the 7th row in Series 1 and 2, the following inequalities should hold:

$$\text{Series 1: } U^C_6(x, p; y, q) > U^B_6(x, p; y, q) \tag{1}$$

$$\text{Series 1: } U^C_7(x, p; y, q) < U^B_7(x, p; y, q) \tag{2}$$

$$\text{Series 2: } U^C_6(x, p; y, q) > U^B_6(x, p; y, q) \tag{3}$$

$$\text{Series 2: } U^C_7(x, p; y, q) < U^B_7(x, p; y, q) \tag{4}$$

We substitute in the utility function, *$U=v(y)+ \pi(p)(v(x)-v(y))$*, given by cumulative prospect theory (with a one-parameter form of Prelec's weighting function), where *$v(x)= (x^{\sigma})$* and *$\pi(p)= exp[-(-log(p))^{\alpha}]$*. We also plug in the numerical values of the gambles. We obtain the following:

$$(2294^{\sigma})+\exp(-(-\log(0.3))^{\alpha})*((9176^{\sigma})-(2294^{\alpha}) > (1147\wedge^{\sigma})+\exp(-(-\log(0.1))^{\alpha})*((28676^{\sigma})-(1147^{\alpha})) \tag{5}$$

$$(2294^{\sigma})+\exp(-(-\log(0.3))^{\alpha})*((9176^{\sigma})-(2294^{\alpha})) < (1147^{\sigma})+\exp(-(-\log(0.1))^{\alpha})*((34411^{\sigma})-(1147^{\alpha})) \tag{6}$$

$$(6882^{\sigma})+\exp(-(-\log(0.9))^{\alpha})*((9176^{\sigma})-(6882^{\alpha})) > (1147^{\sigma})+\exp(-(-\log(0.7))^{\alpha})*((14911^{\sigma})-(1147^{\alpha})) \tag{7}$$

$$(6882^{\sigma})+\exp(-(-\log(0.9))^{\alpha})*((9176^{\sigma})-(6882^{\alpha})) < (1147^{\sigma})+\exp(-(-\log(0.7))^{\alpha})*((15600^{\sigma})-(1147^{\alpha})) \tag{8}$$

We can find ranges for σ and α that satisfy the above inequalities. In this case they are $0.65<\sigma<0.74$ and $0.66<\alpha<0.74$. As in Tanaka Camerer and Nguyen (2010) and Liu (2012), we approximate the values of (σ, α) by selecting the midpoint of each interval. Therefore in this example (σ,

α) are estimated to be (0.7,0.7). Some subjects decide not to switch at any point in the series. In this case the values at the boundary are used (Tanaka Camerer and Nguyen, 2010).

We use a similar set of inequalities to derive our estimates for our parameter for loss aversion (λ). In this case inference depends on two critical pieces of information: the estimate for σ, and the switching point in Series 3. According to Tanaka Camerer and Nguyen (2009) "the probability sensitivity parameter, α, plays no role in Series 3 since all prospects involve equal (50%) chances of gain and loss, so the probability weighting terms drop out in calculating prospect values". Yet again we construct the inequalities based on the assumption that if a subject switches at the N^{th} row, they prefer Cartagena in the $N\text{-}1^{th}$ row, and Bogota in the N^{th} row. Therefore if a subject chooses to switch at the 3^{rd} row in Series 1 and 2, the following inequalities should hold:

$$\text{Series 3: } U^C_2(x, p; y, q) > U^B_2(x, p; y, q) \tag{1}$$

$$\text{Series 3: } U^C_3(x, p; y, q) < U^B_3(x, p; y, q) \tag{2}$$

We substitute in the utility function. Because we are dealing with gains and losses, $U= \pi(p)(v(x))+ \pi(q)(v(y))$ and the value function takes on the two forms: $v(x)= -\lambda(-x^{\sigma})$ for losses and (x^{σ}) for gains. We also choose a value for σ. Here we select σ=0.2.

$$(-\lambda*((\exp[-(-\ln 0.5)])(-917^{0.2}))+ (\exp[-(-\ln 0.5)])(917^{0.2}) > -\lambda*((\exp[-(-\ln 0.5)])(-4817^{0.2}))+ (\exp[-(-\ln 0.5)])(6882^{0.2}) \tag{3}$$

$$(-\lambda*((\exp[-(-\ln 0.5)])(-917^{0.2}))+ (\exp[-(-\ln 0.5)])(229^{0.2}) < -\lambda*((\exp[-(-\ln 0.5)])(-4817^{0.2}))+ (\exp[-(-\ln 0.5)])(6882^{0.2}) \tag{4}$$

We can find the range for λ that satisfy the above inequalities, conditional on a value of σ. Here it is $1.28<\lambda<1.85$. Yet again some subjects decide not to switch at any point in the series. In this case we use the values at the boundary.

The mean values of σ and α are therefore 0.57 and 0.83 respectively. The fact that $\alpha<1$ demonstrates that individuals tend to overweight small probabilities and underweight large probabilities. Furthermore, these values for σ and α are very similar to the estimates from other experiments that use the same design. Tanaka Camerer and Nguyen (2010) estimate average values of (0.59, 0.74) and (0.63, 0.74) in the south and north of Vietnam, respectively. Liu (2012) finds average values of (0.48, 0.69) in China. We also estimate the average value of λ, which is 3.12. This is very similar to Liu's (2012) estimate of 3.47, and slightly higher than the average value calculated by Tanaka Camerer and Nguyen (2010) of 2.63. Tanaka Camerer and Nguyen's (2010) estimate is closer to the value of 2.25 estimated by Kahneman and Tversky (1992).

We use a T-test to reject the null hypothesis that $\alpha=1$ and $\lambda=1$ at the 1% significance level. This means that we can reject EU theory in favor of PT. This validates the use of Tanaka Camerer and Nguyen's (2010) framework to tease out farmers' risk preferences.

Determinants of Preference Parameters

We regress each prospect theory parameter, σ, α, and λ on a series of explanatory variables. We use OLS regressions for σ, α and interval regressions using maximum likelihood techniques for λ. Every regression uses robust standard errors to account for possible heteroskedasticity. Furthermore, we rely on the literature to guide us in our selection of the dependent variables. We choose to include age, household status, gender, education and our proxy for wealth (total value of assets). This is consistent with Tanaka Camerer and Nguyen (2010) and Liu's (2012) papers.

When running the regressions for σ and α we also drop any observations that fail to switch in Series 1 and Series 2 because we are unable to calculate precise estimates for their σ and α. Indeed, when subjects do not switch from lottery Cartagena to Bogota the approximate values at the boundary have to be used. Liu (2012) mentions that for those who do not switch she "arbitrarily" determines the lower/upper bound. Tanaka Camerer and Nguyen (2010) use the same approach. Both sets of authors admit that this could introduce additional noise. We want to avoid introducing random noise, and therefore we choose to drop the observations that cannot be precisely estimated. Similarly in our regression for λ we also dropped observations that did not switch in Series 3.

The regression can be expressed as follows:

$$\sigma=\beta_0+\beta_1(HH)+\beta_2(AGE)+\beta_3(GENDER)+\beta_4(HSCHOOL)+\beta_5(GRAD)+\beta_6(WEALTH)+\varepsilon \qquad (1)$$

$$\alpha=\beta_0+\beta_1(HH)+\beta_2(AGE)+\beta_3(GENDER)+\beta_4(HSCHOOL)+\beta_5(GRAD)+\beta_6(WEALTH)+\varepsilon \qquad (2)$$

$$\lambda=\beta_0+\beta_1(HH)+\beta_2(AGE)+\beta_3(GENDER)+\beta_4(HSCHOOL)+\beta_5(GRAD)+\beta_6(WEALTH)+\varepsilon \qquad (3)$$

The results are detailed in the following Table 4. These results are robust to various different specifications and a range of proxies for wealth. Furthermore these results are robust to dropping the observations with extremely large levels of wealth.

Table 4: Regression Results of Prospect Theory Parameters

VARIABLES	σ Curvature	λ Loss Aversion	α Probability Weight
Head of Household	0.023	-1.318*	0.119*
	(0.0769)	(0.7485)	(0.0687)
Age	0.006***	0.030	-0.003
	(0.0024)	(0.0237)	(0.0021)
Gender	0.122	0.124	-0.027
	(0.0810)	(0.7403)	(0.0717)
High School	0.177***	-0.650	-0.006
	(0.0631)	(0.4976)	(0.0629)
Graduate School	0.323***	-1.789**	-0.163**
	(0.0822)	(0.752)	(0.0749)
Wealth (Proxy)	0.004**	-0.011	0.001
	(0.0016)	(0.0159)	(0.0020)
Constant	0.076	2.967***	0.892***
	(0.114)	(0.9752)	(0.1010)
Observations	140	140	140
R squared	0.194		0.0484
Prob > F	0.0000		0.2286
Wald chi2 (6)		8.97	
Prob > chi2		0.1751	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The first column presents the results we obtain from regressing σ (the curvature of the utility function) on the defined set of explanatory variables. We find that older farmers with higher levels of education are more risk loving. Similarly, wealthier farmers also have a higher tolerance for risk. This result is consistent with Liu's (2012) findings from China. More generally, the literature on whether wealth significantly impacts risk preferences remains inconclusive. Cardenas and Carpenter provide a detailed review of these studies.

We then investigate the factors that influence the loss aversion parameter λ in Table 3. We find that farmers who act as heads of households, and farmers with graduate degrees, are generally less loss averse. Finally we regress the nonlinear probability weighting parameter α on the independent variables. The only determinants to affect this weighting parameter are education and having the status of head of household.

The results from Table 3 identify the primary factors that contribute to risk aversion and loss aversion among Colombian farmers. In the following section we investigate specifically whether risk preferences influence the decision to adopt a new technology and the extent to which farmers adopt. If we find that risk is a significant barrier to adoption, we can then use the results from Table 3 to identify the specific attributes that cause farmers to be risk averse, and hence to refuse the new technology.

Section V: Model and Econometric Framework

The preceding section went through a detailed description of the data collection process. We were successfully able to collect information on our two dependent variables of interest: willingness to adopt and extent of adoption. Furthermore we gathered detailed data on the two potential barriers of adoption: features of the new technology and characteristics of the farmer. Some variables were harder to measure than others. In particular we needed to implement an experimental game in order to assess farmers' individual risk preferences.

The following section details the econometric model we used to answer our two primary questions of interest. Firstly, what factors influence the decision to adopt a new technology? Secondly, what are the main barriers affecting the extent to which a farmer adopts? More precisely we want to determine whether a farmer's risk preferences affects the decision to adopt, and the extent of adoption.

I. Model: Do risk preferences affect willingness to adopt?

A farmer's decision to adopt can be modeled using a random utility framework. The following section provides a detailed overview of the model. A farmer '*n*' faces a choice between two alternatives i (i=1,2). In this case the alternatives refer to two technologies labeled A and B. Technology A represents the status quo technology currently being used by farmers and technology B represents the new alternative. The farmer obtains a certain level of utility from each technology and will chose technology A if it provides a greater level of utility than technology B. The behavioral model can be expressed as follows:

Choose alternative A if and only if

$$U_{nA}(Y_A, C_A, E_A, L_A, R\delta_A, \boldsymbol{X_n}) > U_{nB}(Y_B, C_B, E_B, L_B, R\delta_{B,} \boldsymbol{X_n}) \qquad (1)$$

Where Y is the yield of the technology, C is the cost, E is the environmental/health impact, L is the labor requirements, and R is the farmer's *individual* risk preference (calculated as σ in the experimental game). The parameter δ represents farmers' perception of the *technology's* risk. We assume that $\delta_B > \delta_A$, because a new technology will always be perceived to involve more risk than maintaining the status quo. We hereby refer to $R\delta$ as the farmer's overall risk parameter. The variable '$\boldsymbol{X_n}$' is a vector of farm and farmer characteristics such as age, education, wealth, gender, and land holdings.

Researchers cannot fully observe a subject's utility, and therefore the inequality must be rewritten as follows:

$$V_{nA}(Y_A, C_A, E_A, L_A, R\delta_A, \boldsymbol{x}) + \varepsilon_{NA} > V_{nB}(Y_B, C_B, E_B, L_B, R\delta_B, \boldsymbol{x}) + \varepsilon_{NB} \tag{2}$$

Where V is the deterministic part of the utility function and ε_{NA} and ε_{NB} are i.i.d random variables with zero means. V is observable because it depends on the features of the technology, as well as the characteristics of the farmer. The random variable ε_N contains all the factors affecting utility that researchers cannot observe. The vector $\boldsymbol{\varepsilon_N} = (\varepsilon_{NA}, \varepsilon_{NB})$ has a joint density function $f(\varepsilon_N)$. Moreover, as is typical in the literature, we assume that V is linear:

$$V_{ni} = \beta_0 + \beta_1 \boldsymbol{x} + \beta_2 \boldsymbol{Y_i} + \beta_3 \boldsymbol{C_i} + \beta_4 \boldsymbol{E_i} + \beta_5 \boldsymbol{L_i} + \beta_6 R\delta_i + \varepsilon_i \tag{3}$$

The decision to adopt a new technology can then be expressed in a probability framework as follows:

$$P_{nB} = \text{Prob}\,(U_{NB} > U_{NA}) \tag{4}$$

$$P_{nB} = \text{Prob}\ (\varepsilon_{NA} - \varepsilon_{NB} < V_{NB} - V_{NA}) \tag{5}$$

$$P_{nB} = \text{Prob}\ (\varepsilon_{NA} - \varepsilon_{NB} < \beta_2(Y_B - Y_A) + \beta_3(C_B - C_A) + \beta_4(L_B - L_A) + \beta_5(E_B - E_A) + \beta_6 R\ (\delta_B - \delta_A)) \tag{6}$$

This probability is a cumulative distribution. It is the probability that each random term (ε_{NB} - ε_{NA}) is below a fixed amount (V_{NA} - V_{NB}). In other words the probability that a farmer chooses technology A over B is equal to the probability that the unobserved portion of utility for technology B does not exceed the unobserved portion of utility for A, by an amount greater than (V_{NA} - V_{NB}). We can rewrite the probability statement by using the density function:

$$P_{nA} = \int I\ (\varepsilon_{NB} - \varepsilon_{NA} < V_{NA} - V_{NB})\ f(\varepsilon_N)\ d\ (\varepsilon_N) \tag{7}$$

Where I is an indicator function if (ε_{NB} - $\varepsilon_{NA} < V_{NA}$ - V_{NB}) is true and 0 otherwise. Different discrete choice models are obtained from different assumptions about the distribution of $\varepsilon_{N,}$ the unobserved part of the farmer's utility. In this study we assume the errors are i.i.d extreme value. Therefore (ε_{NB} - ε_{NA}) follows a logistic distribution. We can rewrite the probability statement as:

$$P_{nA} = \frac{e^{V_{nA}}}{\sum_i e^{V_{ni}}} = \frac{e^{\beta_o+\beta_1 x+\beta_2 Y_A+\beta_3 C_A+\beta_4 E_A+\beta_5 L_A+\beta_6 R\delta_A}}{e^{\beta_o+\beta_1 x+\beta_2 Y_A+\beta_3 C_A+\beta_4 E_A+\beta_5 L_A+\beta_6 R\delta_A} + e^{\beta_o+\beta_1 x+\beta_2 Y_B+\beta_3 C_B+\beta_4 E_B+\beta_5 L_B+\beta_6 R\delta_B}} \tag{8}$$

$$P_{nA} = \frac{e^{\beta_2\Delta Y+\beta_3\Delta C+\beta_4\Delta E+\beta_5\Delta L+\beta_6 R\Delta\delta}}{1+e^{\beta_2\Delta Y+\beta_3\Delta C+\beta_4\Delta E+\beta_5\Delta L+\beta_6 R\Delta\delta}} \tag{9}$$

We estimate this model using maximum likelihood estimation techniques. More specifically we run a logit model, which allows us to identify the parameters that are most likely to influence the probability of switching over to a new technology. This requires finding the value of β that maximizes the log likelihood function:

$$LL(\beta) = \sum_{n=1}^{N} \sum_{i} y_{ni} \ln(P_{ni}) = \sum_{i=1}^{2} \left\{ y_{ni} \ln(P_{ni}) + (1 - y_{ni})(1 - \ln(P_{ni})) \right\} \tag{10}$$

II. Econometric Framework: Do risk preferences affect extent of adoption?

When farmers are confronted with a new technology they must first decide whether or not to adopt it. If they choose to do so, farmers must then select how many acres they will devote to the new technology. The previous section went through a detailed explanation of the random utility model we selected to identify the factors that influence the decision to adopt. The model is based on the data we collected from our CE, in which farmers had to choose between two competing technologies.

Next we focus on the second decision facing farmers, regarding the extent of adoption. We follow Cooper's (1996, 1997) econometric approach and model the amount of land farmers intend to devote to the new technology as a function of various explanatory variables. Ideally the dependent variable would be the number of acres that farmers intend to assign to the new technology. Nevertheless, we are not working with a specific technology in this study, and we do not think that it would have been useful to present farmers with a fictitious technology in order to assess the number of acres they would allocate to it. This would have prompted random and uninformed answers. Moreover local agronomists had indicated to us that farmers would only try a new technology if they were given some financial incentive to do so. Therefore it would not be realistic to ask farmers about how much land they would devote to a new technology, since they probably would not do so without some form of monetary compensation.

As a result we ask farmers how much land they are willing to rent out to Cornell University. We explain to the farmers that a team of scientists from Cornell needs the land to test the efficiency of a new, pesticide free, technology suitable for dealing with the potato moth. We determine that this was a good proxy for the amount of land they might to devote to a new technology, should it be offered in the future. This question is asked as a follow up question to the CV question "are you willing to rent land". This becomes our dependent variable of interest.

Contrary to most papers in this field, we opt to use the *amount* of land farmers say they will rent rather than the *proportion* of land, for a number of reasons. Firstly Colombian farmers do not tend to think in percentage terms (as demonstrated by the risk game). Secondly, the question is not designed to elicit responses in percentage terms. Indeed when farmers think about the amount of land they will rent, they rarely exceed 10% of their overall land holdings. Therefore to avoid dealing with miniscule percentages we keep our dependent variable in hectares. Finally we decide to follow Cooper (1996,1997) who publish two significant papers on the use of WTA CVs in order to understand technology adoption. He consistently uses to amount of land, rather than proportion of land, as the dependent variable of interest.

We selected our independent variables among the pool of factors that can potentially impact adoption decisions. A detailed overview of such variables was presented in the literature review. Indeed, there is no reason to believe that the variables affecting adoption should be any different from those affecting the extent to which the farmer will adopt. As a result we include age, gender, education, wealth (proxy by durable goods), individual risk preference (σ), a private and public source of information, total farm size, and the predicted price at which the farmers agreed to rent their land. The majority of these explanatory variables appear in similar studies that use CVs to understand technology adoption (Qaim and de Janvry (2003), Hubbell and Mara, 2000). The variables for private and public information represent our contemporaneous measures of farmers' social networks. This will illustrate whether a farmer's access to social networks has any impact on their decision to adopt.

Furthermore we do not include credit constraints here because, as mentioned previously, we had no prior reason to believe that they would be binding. Firstly, there is widespread access to credit in these areas of Colombia. Approximately 85% of the sample was able to take out loans in the last five years.

Moreover, 80% of participating farmers accessed this credit through some form of financial institution. Secondly, among those households who took out loans, the majority (60%) deemed that the interest rates they were charged were fair. Thirdly, credit constraints are less likely to bind because the new hypothetical technologies we offered to farmers did not require large investments relative to Colombian farmers' income.

Moreover we are the first paper to include a measure of risk preferences in such a model. This variable enables us to determine whether or not a farmer's degree of risk aversion influences the extent to which they adopt. Therefore we have the following reduced form equation:

$$\textbf{HECTARES} = \beta_0 + \beta_1 (Age) + \beta_2 (Gender) + \beta_3 (Educ) + \beta_4 (Risk) + \beta_5 (Private\ Info) + \beta_6 (Private\ Info) + \beta_7 (Total\ Farm\ Size) + \beta_8 (Price) + \beta_8 (Wealth) + \varepsilon_i$$

Where the dependent variable "hectares" is the amount of land farmers are willing to rent to Cornell University. This is a continuous variable, which is recorded for all farmers who answer, "yes" to the hypothetical CV question "are you willing to rent out land". We attribute a value of zero to those farmers who answer 'no' to the CV question, thereby disclosing that they do not want to rent their land at either of the price points offered (400,000 or 600,000 pesos).

This model could have been estimated using OLS, but the results would have been biased because our data is censored. More specifically, OLS estimation using censored data "will lead to inconsistent estimation of the slope parameter since a linear approximation to the censored means will have a flatter slope than that for the original uncensored mean" (Cameron and Trivedi, 2005). To correct for this we use a Tobit model. The Tobit model assumes that the errors are normally distributed and homoscedastic.

Most of the papers that explore technology adoption using CVs employ the Heckman selection model rather than the Tobit, in order to deal with the censored dependent variable. The Heckman model is appropriate when the dependent variable of interest is only observed for a selected sample *that is not* *representative* of the population being considered. In other words the Heckman should be used when the researcher suspects that there is sample selection bias. Hubbell and Mara (2000), De Janvry and Quaim (2003), and Cooper (1996) all argue in their respective papers that the sample of farmers who answer “yes” to the WTA/WTP question regarding adoption is not randomly drawn from the entire population of respondents. Therefore they proceed with the Heckman model.

The Heckman selection model needs to satisfy certain conditions before it can be used for estimation purposes. The Heckman model consists of a selection equation and an outcome equation. The selection equation is used to estimate the probability of being observed, which in this case would be the probability of renting land to Cornell. The outcome equation is then used to explain the outcome variable of interest, which in this case would be the amount of land rented in hectares. For the Heckman model to produce consistent estimates, there needs to be some variables Z that affect the probability of observing the dependent variable of interest Y, without affecting Y directly. In other words there needs to be some variables that affect the “selection” equation but not the “outcome” equation. If this is not the case, then most researchers argue that the Heckman model should not be applied. According to Kennedy, simulations have demonstrated that the Heckman procedure fails to produce consistent estimates when the variables in the selection and outcome equations are highly collinear, (Kennedy 1998).

We decide against the Heckman model because we do not have any obvious exclusion restriction (variables affecting the first stage residual but not directly appearing in the second stage regression). Therefore our outcome and selection equations are the same, which implies that the identification will depend entirely on the non-linearity of the inverse Mills ratio. It then becomes necessary to have enough explanatory variables to allow this non-linearity to impact the outcome. This is very difficult to achieve, and therefore we opted for the Tobit model.

Section VI: Results

We have reviewed the theoretical model and econometric framework for answering the two primary questions of interest. We proceed with our final section, which details our results.

I. Results First Main Outcome: Do risk preferences affect willingness to adopt?

The first set of results identifies the factors that influence farmers' willingness to adopt a new technology. The choice experiment was used to determine whether or not people would switch to a new technology. This represents our measure for their willingness to adopt. The explanatory variables were selected based on the two potential barriers to adoption: the features of the new technology and the personal attributes of the farmers, including risk preferences. These variables were collected from the choice experiment, the questionnaire and the risk game. The regression results from the logit model are presented in the following Table 5. We report the marginal effects. We also use cluster robust standard errors because we have nine observations for each individual. Each observation corresponds to a different decision the farmer made during the choice experiment, which consisted of nine choice sets.

Table 5: Regression Results - Determinants of Willingness to Adopt

VARIABLES	Adopt New Technology
Yield	0.013***
	(0.00169)
Cost	-0.004***
	(0.00085)
More Labor	-0.205***
	(.0388629)
Less Labor	0.162***
	(0.05095)
Healthier	0.394***
	(0.04049)
Cost*Healthier	0.002 **
	(0.00113)
Yield*Healthier	-0.008***
	(0.00243)
More Labor*Healthier	0.117**
	(0.05088)
Less Labor*Healthier	-0.105
	(0.09512)
Risk Parameter (R (δ_B -δ_A))	0.055
	(0.05764)
Constant	0.0647
	(0.219)
N	1260
Wald chi2 (10)	182.39
Prob > chi2	0.0000

*** p<0.01, ** p<0.05, * p<0.1

Our main finding is that only one of the two potential barriers to adoption actually impacts the probability of adopting. Indeed, the decision seems to rest solely on the features of the technologies themselves: namely, whether they provide more yield, require less labor and fewer costs, and whether they protect the environment. Conversely, farmers' levels of education, age, gender and other social factors do not seem to impact the decision to adopt. Most importantly farmers' risk parameter is not significant. The Wald test suggests that this model is a good fit for the data. Moreover the model is robust to different specifications. We tried interacting the risk parameter with different features of the new technology but this did not change the results.

A more detailed analysis of the results reveals which attributes of the technologies farmers' value most. We first analyze the main effects of each attribute from their respective coefficient estimates. Firstly, their decision to adopt relies heavily on the technology's environmental and health impact. Indeed if a technology is healthier the farmer is at least 39% more likely to adopt it. This assumes that all the other features of the new technology are the same as the status quo. During the survey process farmers repeatedly expressed their concerns over the heavy use of pesticides in the region. They understood the consequences of over-exposure and were interested in learning about new ways to reduce the use of toxic chemicals.

Secondly, farmers tend to focus on the labor requirements of the technology. A farmer is 20% less likely to adopt the new technology if it requires more labor, all else equal. Conversely they are 16% more likely to adopt if the technology has fewer labor demands. Potato cultivation is particularly labor intensive, and the majority of farmers in the sample were already working full time on their own land. They also had to hire external labor during peak seasons (planting and harvesting). As a result it was hard for them to conceive of providing more labor, whereas they welcomed the opportunity to supply less.

Finally Table 5 demonstrates that a technology's estimated yield and cost levels influences farmers' decision to adopt. These variables are measured continuously and therefore a 1-unit increase in yield leads to a 1.2% *increase* in the probability of adopting all else equal. Conversely a 1-unit increase in cost *decreases* the probability of adoption by 0.4%. Yields are measured in "cargas", where one "carga" is 100 kilograms, and costs are measured in pesos. At first glance, the impact of yield and cost seem rather low. Nevertheless the alternative technologies we present to farmers produced up to 30 more cargas (3000 kilos) and could increase in cost by 75,000 pesos (40 US dollars). Based on the previous results, a farmer would be 36% more likely to adopt a technology that produced 30 more cargas (3000 kilos). Similarly a farmer would be 29% less likely to adopt a new technology that demanded 75,000 more pesos (40 US dollars).

We also include three interaction terms in the reduced form equation. The interaction terms reveal the importance that farmers place on health. More specifically, these variables reveal the extent to which farmers are willing to make compromises with regard to the three other attributes of the technology (lower yield, higher cost, more labor), in exchange for a healthier technology. Firstly, as we have seen, the coefficient on cost is negative, suggesting that farmers are less likely to adopt if the technology is more expensive. Moreover, the coefficient on the term “cost*health” is positive. This indicates that farmers are “less unwilling” to switch to a new technology that is more expensive, if they know it to be healthier. Accordingly, while a 1-unit increase in cost decreases the probability of adoption by 0.4%, the probability only decreases by 0.2% if the technology is also healthy/environmentally friendly.

Secondly we have established that the coefficient on yield is positive, which indicates that farmers are more likely to adopt a new technology if it provides a higher yield. Moreover the coefficient on the interaction term “yield*health” is negative. This indicates that farmers do not place as much emphasis on a yield increase if the technology already boasts a lower environmental impact. More specifically the probability of adoption falls from 1.2% to 0.46%.

Finally, we have determined that the probability of adoption is inversely correlated with the amount of labor the technology requires. Moreover the coefficients on the interaction terms “more labor* healthier” and “less labor* healthier” are positive and negative respectively. So while an increase in labor leads to a decrease in the probability of adoption by 20%, this percentage is reduced to 9% if the technology has a lower environmental/health impact. Yet again this indicates that farmers become “less unwilling” to adopt a technology that requires more labor, if they know it to be healthier. Furthermore, while a decrease in labor generates a 16% increase in the probability of adopting, this percentage falls to 6% when the technology is more environmentally friendly. This illustrates that the farmer considers the technology's labor requirements to be less important if he/she already knows it to be healthier.

These results indicate that the decision to adopt a new technology is heavily based on the attributes of the technologies themselves. Moreover the decision does not seem to depend on a farmer’s personal characteristics. Indeed the coefficient on the risk parameter is positive but not statistically insignificant.[25] Furthermore, we investigate the impact of several additional characteristics such as age and gender on the decision to adopt, by including various interaction terms in the regression. We test several different models with a wide range of interactions terms, but they all proved to be insignificant. As a result, we conclude that the decision to adopt a new technology is primarily determined by the attributes of the technologies themselves rather than a farmer's personal characteristics.

These results are better understood in the context of the study's specific sample of farmers. Indeed the majority of farmers are connected with the local potato association (FEDEPAPA). They often interact with the institution's agronomists, who travel regularly to the village, or to the farmers' homes, to recommend new farming strategies. Therefore, our sample of farmers is familiar with the process of adopting new technologies. We might expect that they would weight the characteristics of the new technologies we are currently offering more heavily than anything else. Furthermore our sample of farmers has self-selected into this association which means they already place value on being part of a group that promotes best practices in potato farming.

II. Results Second Main Outcome: Do risk preferences affect extent of adoption?

We began by identifying two potential barriers to adoption: features of the new technology and personal characteristics of the farmer. Our analysis reveals that a farmer's decision to adopt depends on the former but not the latter. Indeed we successfully established that farmers are much more likely to adopt a new farming technique if they value the features it possesses. We also find that farmers' personal characteristics such as age, gender, and education do not significantly influence the decision. Of particular interest is the fact that a farmer's preference for risk does not seem to have any impact on the decision to adopt a new technology.

[25] This indicates that as farmers risk parameter increases, the probability of adopting goes up. Recall that the risk parameter is comprised of two elements: the farmer's individual risk preferences and their perception of the technology's risk. As it stands we are unable to separate the effect of these two variables. Indeed we do not know whether the coefficient we are finding on this risk parameter term is driven primarily by the farmer's personal risk preferences or their risk perception. The reason this is so difficult to interpret is because farmers' risk perception is almost certainly some function of their risk preference. We leave this for future research, as it is not relevant to the current study since this risk parameter is insignificant to begin with.

While personal characteristics such as risk preferences may not affect the probability of adoption, they still have the potential to determine the extent to which farmers adopt. More specifically, we hypothesize that farmers who are more risk loving will devote a greater percentage of their land to the new technology. In order to test this hypothesis we made use of a CV question as detailed in the previous section. Our dependent variable of interest is the amount of land farmers are willing to rent to Cornell University in order for their scientists to test the efficiency of a new technology on the potato crop. This serves as a proxy for the amount of land they would devote to a new technology should it become available. It is also our measure for extent of adoption. The results are provided in Table 6.

We report three different marginal effects. There is some debate as to which of these effects should be reported in a Tobit model. We decided to provide all three for completeness. First we state the marginal effects on the expected value of the latent dependent variable y^*. Second we display the marginal effects on the expected value of the dependent variable y, for all observations. Finally we report the marginal effects on the expected value for y given $y>0$ (for censored observations only).

Table 6: Regression Results – Determinants of Extent of Adoption (Marginal Effects)

	Latent y $\frac{\partial E[y^* \mid x]}{\partial x}$	Observable y $\frac{\partial E[y \mid x]}{\partial x}$	Censored y $\frac{\partial E[y \mid x, y>0]}{\partial x}$
Risk (σ)	0.517*	0.397*	0.285*
	(0.2842)	(0.2185)	(0.1574)
Head of Household	-0.041	-0.031	-0.022
	(0. 2482)	(0.1917)	(0.1378)
Age	-0.007	-0.005	-0.004
	(0.0089)	(0.0068)	(0.0049)
Gender	0.184	0.141	0.101
	(0.2687)	(0.2064)	(0.1485)
High School	0.008	0.006	0.004
	(0.2483)	(0.1906)	(0.1370)
Graduate School	-0.191	-0.146	-0.105
	(0.3252)	(0.2493)	(0.1792)
Advice Farmers	0.325*	0.249*	0.179*
	(0.1902)	(0.1462)	(0.1051)
Advice FedePapa	-0.067	-0.051	-0.037
	(0.2914)	(0.2236)	(0.1608)
Wealth (Proxy)	0.005	0.004	0.003
	(0.0065)	(0.0037)	(0.0037)
Total Farm Size	-0.003	-0.002	-0.001
	(0.0049)	(0.0037)	(0.0027)
Price	-0.007	-0.006	-0.004
	(0.0056)	(0.0044)	(0.0031)
Constant	3.654	3.654	3.654
	(2.917)	(2.917)	(2.917)
N	136	136	136
LR chi2 (10)	11.96	11.96	11.96
Prob > chi2	0.3252	0.3252	0.3252

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Our main finding is that farmers' risk preferences significantly impact the extent to which they adopt a new technology. More specifically, we find that as farmers become more risk loving, they are willing to rent out more land. Accordingly, a one-unit increase in farmer's risk preferences causes them to rent out an additional 0.5 hectares of land (or by 0.4 hectares if we are looking at the dependent variable y in Column 2; and by 0.29 if we are looking at the censored observations only in Column 3).

Additionally, we find that farmers' interaction with their social network also influences the amount of capital they are willing to invest in a new technique. Indeed, farmers seeking regular advice from others are willing to rent out an additional 0.3 hectares of land (or by 0.25 hectares if we are looking at the dependent variable y in Column 2; and by 0.18 if we are looking at the censored observations only in Column 3). The remaining personal characteristics such as age, gender, and education do not significantly impact the extent to which farmers adopt a new technology. Nevertheless the signs on the coefficients are exactly what we would expect (more educated, younger males will rent out the most land).

We also conducted a number of robustness checks by formulating alternative specifications for the reduced form equation. The results are presented in the following Table 7. For these alternative models we only report the marginal effects on the expected value of the dependent variable y, for all observations. The impact of risk and social networks remains almost exactly the same across each model:

Table 7: Regression Results – Determinants of Extent of Adoption (Robustness Checks)

	$\frac{\partial E[y\mid x]}{\partial x}$	$\frac{\partial E[y\mid x]}{\partial x}$	$\frac{\partial E[y\mid x]}{\partial x}$
Risk (σ)	0.397*	0.378*	0.367*
	(0.2185)	(0.2161)	(0.2058)
Head of Household	-0.031	-0.039	
	(0.1917)	(0.1907)	
Age	-0.005	-0.004	
	(0.0068)	(0.0064)	
Gender	0.141	0.124	
	(0.2064)	(0.2043)	
High School	0.006	0.025	0.105
	(0.1906)	(0.1818)	(0.1606)
Graduate School	-0.146	-0.188	-0.237
	(0.2493)	(0.2368)	(0.2275)
Advice Farmers	0.249*	0.252*	0.230**
	(0.1462)	(0.1458)	(0.1429)
Advice FedePapa	-0.051		
	(0.2236)		
Wealth (Proxy)	0.004	0.003	0.003
	(0.0037)	(0.0047)	(0.0047)
Price	-0.002	-0.004	
	(0.0037)	(0.0031)	
Total Farm Size	-0.006		
	(0.0044)		
Constant	3.654	2.833	0.106
	(2.917)	(2.005)	(0.2173)
N	136	136	136
LR chi2 (10)	11.96	11.84	10.05
Prob > chi2	0.3252	0.2007	0.0737

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

These results highlight the importance of understanding farmers' risk preferences, as well as their access to social networks. Farmers are more likely to invest a greater share of their personal assets in a new technique if they have a higher tolerance for risk, and if they interact frequently with their social network. This finding is similar to Liu's results from China, and stresses the need for future papers to include measures for risk preferences and social networks when attempting to analyze the decision to adopt a new technology.

In the previous section we reviewed the main factors that contribute to risk aversion. Furthermore we have now established that risk aversion influences the extent to which farmers adopt.

Considered together, these conclusions can be of good use to policy makers. Firstly, policy makers now have reason to target the technology towards individuals who tend to have lower levels of risk aversion (Table 7). In the case at hand, those individuals have been identified as male, older and wealthier (Table 5). Secondly, our implementing partners can develop programs to target the factors that contribute to risk aversion. For example, Table 5 illustrates that wealth levels influence risk preferences. This means that programs that either increase household wealth or decrease the cost of the technology have a good chance at reducing farmers' level of risk aversion. From Table 7 we see that this can, in turn, increase the amount of land farmers will devote to the new technology.

Section VI: Conclusion

In 2009 entomologists at Cornell University discovered a pesticide-free technology suitable for dealing with Colombia's predominant potato pest, and wanted to know whether it would be feasible to implement it among local farmers. The current study set out to determine which factors would most likely influence Colombian potato farmers' decision to adopt such a technology, and the extent to which they would adopt. More specifically, we hoped to address whether risk preferences would affect either one of these decisions.

To this end, we led a two-month field experiment in order to collect measures for farmers' willingness to adopt a new technology and the extent to which they would adopt. We also gathered information on two potential barriers to adoption: the features of the new technologies and the individual characteristics of the farmer. Firstly, we designed a choice experiment and a contingent valuation question to measure adoption and extent of adoption. Secondly, we used a questionnaire and designed an experimental game to collect information on farmers' personal characteristics and, more specifically, their risk preferences.

We conducted this data collection process before diffusion took place. This way, the information we collected could be passed on to both scientists and implementing partners alike. The former could address prevailing issues with the technology's design while the latter could tackle any social barriers to adoption.

Our results can be summarized as follows. Firstly, we find that only one of the two potential barriers to adoption significantly impacts the decision to adopt a new technology. Indeed farmers place a lot of emphasis on the features of the technique. They are much more likely to adopt the new technology if it provides higher yields, lower labor requirements and lower costs. Moreover, farmers greatly value the health-related and environmental benefits of the technology as well. More specifically, farmers are willing to make sacrifices in terms of the technology's other attributes (yield, cost, and labor) if they can be sure that it will have fewer health impacts. Conversely, farmers' personal characteristics, and most importantly their risk preferences, do not impact the decision to adopt. This can potentially be attributed to the fact that the sample of farmers we were working with had already self-selected into FEDEPAPA, an association that emphasizes innovation and efficient farm management.

The second main result concerns the extent to which farmers adopt a new technology. Here we find that farmers' personal characteristics do matter. Indeed farmers that receive advice from others, and those who are more risk loving, are more likely to devote more of their land to the new technique.

The paper makes two important contributions. Firstly it highlights certain key barriers to adoption. As mentioned previously, the most important include the features of the technologies themselves. Many of the ex-post studies tend to overlook the fact that the technology's characteristics might not suit the farmers' needs. They begin with the assumption that the technology is optimal for farmers and then try to assess why adoption rates remain low. Furthermore we find that the factors that influence the decision to adopt are not necessarily the same as those that motivate extent of adoption. Indeed while risk preferences and social networks do not play a role in the decision to adopt, they do influence the number of hectares the farmer devotes to the new technique.

Secondly this paper makes a contribution to policy, which is much harder for ex-post studies to do. The results we derive from this paper can now be transferred to the scientists and implementing partners involved in this project. Both parties can use this information to ensure higher adoption rates. On the one hand our results provide scientists with concrete evidence that their push pull technique will be well received by this group of farmers. Indeed the new technology provides significant health benefits without demanding drastic increases in costs, labor or yield. The scientists also now know that farmers are willing to make small sacrifices in terms of costs, yield and labor for the benefit of a healthier technique. However these sacrifices cannot be too large, as they will deter some farmers from adopting altogether, as well as reduce potential adopters enthusiasm for the technique.

Implementing partners can also make valuable use of this information. Specifically, policy makers can invest in risk coping mechanisms by providing subsidies for the new technology. Moreover, they can actively recruit farmers to participate in groups like FEDEPAPA, which foster discussions with other farmers and agronomists about best practices in potato farming. Implementing partners can also use this information to try and diffuse the technology in the most efficient way possible. The data supports the strategy of first introducing the technology to the most influential farmers in the community. This way they can be sure that more farmers will discuss the technique with the lead farmers.

This transfer of knowledge illustrates the value of doing *ex-ante* studies when analyzing farmers' willingness to adopt new technologies. It encourages policy makers to try and understand the factors that will prevent farmers from adopting before actual diffusion takes place. Funds can then be directed towards developing useful programs and that will ensure higher adoption rates among farmers, rather than towards costly programs that diffuse a technology, which does not appeal to the community. There are only a handful of studies that try to assess farmers' *willingness* to adopt before diffusion takes place. Moreover there are no papers, to this author's knowledge, that use this *ex-ante* approach to assess the impact of risk preferences, on adoption decisions.

There exist a number of other possibilities for future research. Firstly, we could try to diffuse the technology in two potato growing regions within Colombia. In one of these areas we could use our results from this *ex-ante* study to inform how diffusion should take place. In the other region we could diffuse the technology without considering the results from this study. The goal would then be to establish whether adoption rates are higher in the region where implementing partners considered the results from this *ex-ante* study. Finally, it would be interesting to derive a model of ambiguity aversion and test whether or not this influences the decision to adopt a new technology. This has only been done once before and merits further investigation.

Section VII: Appendix

A. Appendix 1: Questionnaire (with Contingent Valuation Question at the end)

REGISTRATION

Interviewer #: _ _ _

Date: _ _ / _ _
Day / Month

Time Started: _ _ / _ _
Hour / Minute

Time Ended: _ _ / _ _
Hour / Minute

Respondent Name: ______________________________

Respondent ID _ _ _ _ _

00. Head of Household
01. Spouse of Head of Household
02. Child of Head of Household
03. Other Household Member

HEAD OF THE HOUSEHOLD:
is a person among the group of householders who is responsible for satisfying daily necessities of the household or a person who is regarded/assigned as the head of the household.

HOUSEHOLDER:
is anyone who usually lives in the household, whether she/he is at home during the survey or is temporarily absent. A householder who has been away for 6 or more months, and a householder who has been away for less than 6 months but plans to move out/be away for 6 or more months is not regarded as a householder. A guest who has stayed in the household for 6 or more months or a guest who has stayed in the household for less than 6 months but plans to stay for 6 or more months is regarded as a householder. (The name of a householder is to be written on one line only.)

Province: ______________________

Municipality: ____________________

Village: _____________________

How many years have you lived in this municipality? _______Years

Do you plan on moving in the next 10 years? Yes _____ No_____

HOUSEHOLD CHARACTERSITICS

0. What is your position in the household?	Head of Household ……………………………………01 Son of Head of Household ……………………………02 Wife of Head of Household ……………………………03 Father of Head of Household …………………………04 Other Family Member... ………………………………..05
1. How many householders live under your roof (including yourself)	__________ People
2. How many are above 60 years of age?	__________ People
3. How many are below 6 years of age?	__________ People
4. How many are between 6 and 25 years of age?	__________ People
5. How many of those aged 6-25 went to school in the last year?	__________ People
6. How many of those aged 6-25 worked in the last year?	__________ People
7. Does your spouse earn income independently from you?	Yes ……………………………………………………01 No ………………………………………………………02
8. What is the size of your dwelling (square meters)	_________ Square Meters
9. What type of material is used for the floors of your dwelling	Tile………………………………………………………01 Brick/Cement ……………………………………….02 Earth …………………………………………………03 Wood …………………………………………………04 Other ____________________________________05

9. How old are you?	_________ Years
10. What is your gender (interviewer can complete this on his or her own)	Female …………..01 Male ……………..02
11. What is your highest level of education?	No Primary Education …………………………………01 Primary ……………………………………………….02 High School (Academic)………………………………03 High School (Technical) ………………………………04 Vocational College ……………………………………05 Undergraduate ………………………………………06 Master's/ Doctorate …………………………………07
11. What is the highest level of education of your children?	No Primary Education …………………………………01 Primary ……………………………………………….02 High School (Academic)………………………………03 High School (Technical) ………………………………04 Vocational College ……………………………………05 Undergraduate ………………………………………06 Master's/ Doctorate …………………………………07

HEALTH

In general, how is your health?	Very healthy ....01 Somewhat healthy ….... 02 Somewhat unhealthy…..03 Unhealthy 04
During the last 4 weeks, how many days of your primarily daily activities did you miss due to poor health?	______________ days
In the last 4 years have you experienced any serious health problems (requiring hospitalization)?	Yes ……………………. 01 No ……………………. 02
4. Have you or a member of the household experienced one of the following illnesses?	Frequent Headaches/ Fevers………..….01 Nausea/vomiting ………..……………….02 Difficulty breathing…………………………03 Skin infection ………………………………04 Cancer ……………………………………..05 Complications in Pregnancy …………...06
5. How often do you suffer from these illnesses?	Rarely ……………………………..…………01 Occasionally ……………..……………….02 Frequently………………………..……….03

Now we would like to ask about health and pesticides

Do you think pesticides **greatly** harm your health?	Strongly Agree ……………...01 Moderately Agree …………..02 Agree ………………………...03 Disagree ……………………..04 Strongly Disagree……….…..05
Where do you keep the pesticides?	In the kitchen ………….…...01 In the home ……..................02 Outside ….........................03
Which of the following elements do you use to protect yourself from pesticides?	Gloves ……………………….01 Mask (Cloth)…………………02 Coveralls…………………….03 Glasses …………………......04 Boots…………………………05 Mask (Industrial)…………….06
From where do you get your drinking water?	Private Piped water into dwelling ………………..01 Private Piped water into compound/plot…………02 Community piped water (public tap) …………….03 Water vendor……………………………………….04 Neighboring household…………………………...05 Bottled water……………………………………….06 River, lake, spring, pond…………………………07 Rain catchment tank………………………………08 Other………………………………………………..09
Do you take extra precautions to treat your water?	Yes ……………………… 01 → Skip No ……………………… 02 ↓ Next Question
What degree of importance do you attach to the presence of clean water/air environment?	Very Low ………………..01 Low ……………………...02 Average …………………03 High ……………………..04 Very High ………………05

FARM CHARACTERISTICS

How many years have you been farming?	______________ **Years**
What is the ownership status of your farm?	Own it alone ……………….……01 ↓ Next Question Rent it only …………………..…. 02 Own it in a partnership…..…….03 Own and rent…………………...04
Estimate the size of the farm in square meters	______________ **Square meters**

Now we would like to ask you about what you produce:

Crops	1	2	3
Mention at most three main crops grown by this household (which includes different varieties of the same crop)			
What is the average yield of this crop?	________ tons/ hectare	________ tons/ hectare	________ tons/ hectare
What percentage of your land do you allocate to this crop	______________ %	______________ %	______________ %

Do you own livestock?	Yes ……………………….01 No …….…………………02				
How much income did you earn from your livestock?		Quantity	Price	Months	Annual Value
	Milk				
	Eggs				
	Meat				

What percentage of your land do you allocate to raising these animals?	____________ **Hectares**
Are you planning to allocate more land to livestock over crops in the future	Yes ………………….01 No ……………………02

Now we would like to ask you about your growing practices:

How many times in a cropping season do you spray your field with insecticide to control for the Guatemalan Potato Moth?	______________________ Sprays/ Cropping Season
How many times a month do you apply fungicide to your fields?	_______________________Applications/ Month
Do you apply different amounts of pesticide for different crop varieties?	Yes ....01 No. 02
Do you use organic fertilizer?	Yes ....01 No. 02
Do you use chemical fertilizer?	Yes ....01 No. 02
Do you have an irrigation system?	Yes ....01 No. 02
Why did you choose to use these specific types of pesticide / herbicide / fungicide?	Advice of agricultural officer? ………………01 Advice of crop buyer? ………………………02 Received for free? ……………………………03 Cheap …………………………………………04

	Own Experience/ Works best……………….05 Neighbor Advice …………………………….06 Other: ______________________ ……..07
Where did you buy most of pesticide / herbicide / fungicide?	Private Distributor in the Village………….01 Cooperative/ Farmer's association……….02 Relative/ Friend ……………………………03 Neighbor/ Fellow Farmer ………..……….04
How do you deal with the pests that attack your crops during a relatively bad year?	Increase Pesticide Use……………..01 Maintain similar practices ………….02 Decrease Pesticide Use …………...03 Change methods altogether ……….04 Other …………………………………05

Now we would like to ask about selling practices:

How much did you sell in the last harvest?	_____________________ tons/ hectare
What is the market price of the most recent harvest?	_____________________ pesos
What was total revenue from the most recent harvest (without discounting costs)	_____________________pesos
On average, what percentage of the potatoes grown was damaged and could not be sold?	_____________________**%**
How many workers do you employ on your farm	_____________________workers

Now we would like to know about your exposure to IPM:

Have you heard of Integrated Pest Management Strategies (IPM)?	Yes …………………………. 01 ↓ Next No …………………………. 02 → Skip
Have you attended any seminars/ conferences/ talks on IPM?	Yes …………………………. 01 ↓ Next No …………………………. 02
Have you adopted any IPM strategies *Circle all that apply*	Zero Pesticide Use……………………...........01 Good soil preparation ………………………… 02 Deep planting ………………………………… 03 High row cultivation……….............................04 Timing of harvest…………..……………………05 Management of crop residues …....................06 Use of sexual pheromone traps ……………...07 Cleaning and disinfection of storage site …….08 Use of baculovirus as inoculant ……………….09
Do you believe that a natural spray (which doesn't use pesticides) can be as effective at killing pests?	Yes …………………………. 01 ↓ Next No …………………………. 02 → Skip
I am willing to take risks with new technologies before I see good results in other farms	Strongly Agree ……………...01 Moderately Agree …………..02 Agree ………………………...03 Disagree …………………….04 Strongly Disagree………….05

HOUSEHOLD INCOME/ SAVINGS/ CREDIT AND INSURANCE

We would now like to ask about your Income

Approximately how much net profit did you gain last year **from farming**, after taking out all your business expenses?	______________________ Pesos
What was your total household **income** from sources such as government programs (subsidies), support from FEDEPAPA	_____________________ Pesos
What was the total household **revenue** in the past year from **all sources** including farming, government programs, part time labor, livestock, and remittances (best guess)	______________________ Pesos
Do you have a secondary occupation?	Yes ……………….. 01 No …………………. 02
Have you searched for work off the farm?	Yes ……………….. 01 No …………………. 02
Approximately, what percentage of your total revenue comes from your farming activities?	______________________ %

Now we would like to ask you about major expenses

How much do you spend on average on food per **month**?	_________________Pesos
How much do you spend on average per **month on school/ education**?	_________________Pesos
How much do you spend on average per **month** on transportation?	_________________Pesos
How much do you spend on average per **month** on public services?	_________________Pesos
How much do you spend on average per **month** on household items?	_________________Pesos
How much do you spend on average per **month** on leisure?	_________________Pesos
How much do you spend on average per **month** on taxes?	_________________Pesos
How much do you spend on average per **month** on medicine?	_________________Pesos
How much do you spend on average per **month** on other items?	_________________Pesos
How much do you spend in total per month and year	___________ Pesos/ Month ___________Pesos/ Year

Now we would like to ask you about your savings

How much do you save on average per year?	_______________________ pesos
How do you save your money?	In a piggy bank ……………………………………01 In a formal bank ……………………………………02 Invest in livestock …………………………………03 Invest in other …………………………………..…04
What do you save for primarily?	To buy or renovate a house ……….……………..…………01 To buy land …………………………,…………………..…..02 To buy livestock ……………………………………….......03 To protect oneself against unpredictable crop loss ……..04 To invest in new machinery ………………………………..05 To invest in new technologies ……...……………………06

	To invest in a new business ……………………………….07 To pay ones loans ………………………………………….08 To send ones children to University ....09 To travel/spend on leisure …………………………………10 To pay for religious ceremonies…………………………......11 To take care of ones parent………………………………...12 I do not have anything to save for …………………………...13 Other……………………………………………………………...14

We would like to know about your credit access and history

How much credit/ loans were you given by friends, family and financial institutions in the last five years?	______________________ Pesos
Do you have any outstanding debt?	Yes ……………………………01 No …………………………….02
Will you be able to pay back your loan in a timely fashion?	Yes ……………………………01 No …………………………….02
How often do you take out loans?	Every 6 months ………………………………….01 Every year ……………………………………….02 Every 5 years …………………………………….03 Almost never ……………………………………..04
In your opinion, are financial institutions willing to loan you money?	Yes ……………………………………..…………….01 No ……………………………………………..…..02 I never take loans from financial institutions……..03
Have you ever been denied a loan by the Government, bank or other financial institutions?	Yes …………………………. 01 ↓ Next No …………………………. 02 → Skip
What are the major reasons you were denied credit	Insufficient collateral ………………………………..01 Main source of income has too much price risk ….02 I have failed to repay a loan in the past……………03 Bank does not believe I am trustworthy……………04 The repayment schedule required by the bank lender does not match the timing of sales from my small business ……………………………………..05
Is there a period in the year where you are financially constrained?	Yes ……………………………01 ↓ Next No …………………………….02 → Skip
In which period of the year are you financially constrained?	

	Planting	Maintenance	Harvest
1 cycle			
2 cycle			
Observations:			

Now we would like to ask about insurance

Do you have access to insurance?	Yes …………………………. 01 ↓ Next No …………………………. 02 → Skip

HOUSEHOLD ASSETS

Type of Assets	Do you or does any other member of the household own […]?	What is the total value of […] (including renting)	How many years have you had […]	Do you owe any money for the purchase of […]
House and Land	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
Livestock	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
Cars	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
Motorbikes	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
Bicycles	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
TV	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
Radio	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
Washer	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
Fridge	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
Computer/ Camera	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
Tractor	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02
Heavy equipment's (like farming machines, generator, etc.)	01. Yes ------> 02. No ↓ **Next Line**	__________ Pesos	0-5 years ….01 5-10 years …..02 10-15 years ...03 15-20 years ….04 Entire Life……..05	Yes ………….. 01 No……………. 02

HOUSEHOLD SHOCK

Has this household gone through one of the following shocks within the past 5 years?	Crop Loss ………………………………..……………………………..01 Increased Input Prices (chemicals, fertilizer…)……………………..……02 Increased Labor Costs……………………………..………..……….03 Decrease in the Price of Potatoes …..………………….......................04 Job Loss ……………………………..……...……………..….………..05 Death of a family member ……………………………..………………06 Sickness of a householder that required hospitalization or continuous medical treatment ………………………………………….………………07 Extreme Weather Events, …………………………………..……...…..08
Has this household gone through one of the following shocks within the past 12 months?	Crop Loss ………………………………..……………………………..01 Increased Input Prices (chemicals, fertilizer…)……………………..……02 Increased Labor Costs……………………………..………..……….03 Decrease in the Price of Potatoes …..………………….......................04 Job Loss ……………………………..……...……………..….………..05 Death of a family member ……………………………..………………06 Sickness of a householder that required hospitalization or continuous medical treatment ………………………………………….………………07 Extreme Weather Events, …………………………………..……...…..08
Please indicate which two of these economic shocks were most severely felt by your household	______________(code) _____________(code) *Most important* *Second most important*
What steps have been taken by household members in response to these difficulties (circle all that apply)	00. Adapt 01. Use Savings 02. Change Crop/ Land use 03. Change Agricultural Practices 04. Plant less Potato Seeds 05. Sell Land/ Possession 06. Consume Less 07. Take out a loan 08. Reduce Spending 09. Receive outside assistance 10. Reduce hired labor 11. Take an additional job 12. Other ____
Which groups/ organizations do you rely on to help cope with these risks	00. None 01. Farmers Association/ Cooperative 02. NGO 03. Government 04. Family 05. Friend 06. Businessman 07. Other _____

INFORMATION DISSEMINATION

	Do you, or one of your family members, engage in […]	How often do you, or one of your family members, engage in […]
Reading the newspaper	01. Yes ---------------------> 02. No ↓Next	Every day ……………………..…..…….01 Once a week…………………………02 Once a month ……………………….03 Once a year……………….…………04
Listening to the radio	01. Yes ---------------------> 02. No ↓Next	Every day ……………………..…..…….01 Once a week…………………………02 Once a month ……………………….03 Once a year……………….…………04
Surf the internet	01. Yes ---------------------> 02. No ↓Next	Every day ……………………..…..…….01 Once a week…………………………02 Once a month ……………………….03 Once a year……………….…………04
Watching TV	01. Yes ---------------------> 02. No ↓Next	Every day ……………………..…..…….01 Once a week…………………………02 Once a month ……………………….03 Once a year……………….…………04
Do you consider yourself to be well informed about the daily events in your community or region?		Strongly Disagree ………………………..01 Disagree ………………………….……...02 Neutral…………………………………03 Agree ………………………….……...04 Strongly Agree ………………….……05
Which individuals are most influential in the community?		Religious Leader……………………………..01 Mayor ……………………………………......02 Community Member…………………………03 Extension Agent……………………......…04 Other………………………………………..05
How often do you discuss farming techniques with fellow potato growers?		All the time …………………………..01 Often…………………………………..02 Occasionally……………………………03 Rarely ……………. ………………...04 Never…..…………………………………05

Information Source	Did you receive advice for your agricultural activities from any of the following sources in the last 6 months?	How many times did you or any other member of your household visit or meet with [SOURCE] in the last 6 months	Have you put any of the information/ advice from [SOURCE] into practice?	How would you rate the information/ advice received?
FEDEPAPA, or another farmers association	Yes ----------> No ↓Next	Every Day ….01 Every Week ...02 Every Month…03 Every 6 Months...04	Yes ----------> No ↓Next	Very Useful ………..01 Somewhat Useful…02 Not Very Useful……03 Not Useful…………04 Other……………….05
Umata	Yes ----------> No ↓Next	Every Day ….01 Every Week ...02 Every Month…03 Every 6 Months...04	Yes ----------> No ↓Next	Very Useful ………..01 Somewhat Useful…02 Not Very Useful……03 Not Useful…………04 Other……………….05
NGO/Research organization	Yes ----------> No ↓Next	Every Day ….01 Every Week ...02 Every Month…03 Every 6 Months...04	Yes ----------> No ↓Next	Very Useful ………..01 Somewhat Useful…02 Not Very Useful……03 Not Useful…………04 Other……………….05
Private Company	Yes ----------> No ↓Next	Every Day ….01 Every Week ...02 Every Month…03 Every 6 Months...04	Yes ----------> No ↓Next	Very Useful ………..01 Somewhat Useful…02 Not Very Useful……03 Not Useful…………04 Other……………….05
Peer Farmer (Neighbor/ Relative)	Yes ----------> No ↓Next	Every Day ….01 Every Week ...02 Every Month…03 Every 6 Months...04	Yes ----------> No ↓Next	Very Useful ………..01 Somewhat Useful…02 Not Very Useful……03 Not Useful…………04 Other……………….05

Have you participated in an agricultural project, run by an NGO and/or a research organization, before?	Yes ………………………. 01 No ……………………….. 02
What year was the last project that you took part in?	____________________ Year
Have you ever rented your land for agricultural projects related to IPM?	Yes ………………………. 01 No ……………………….. 02

Finally we would like to know how much money you would be willing to accept to participate in a future Cornell study run by a team of University biologists. This would require renting one quarter of a hectare of your fields to the team, who would like to use the land to test the effectiveness of a new pesticide free technology. The team will cover all the expenses associated with the experiment, including all necessary materials and labor costs.

The team has already run this experiment with 15 other farms in the region, and they would like to do it again with more farmers in different regions. The price that they will be able to pay will stay between 400,000 and 600,000 pesos for a quarter of a hectare

1. Would you be willing to rent a quarter of a hectare of your land to the researchers from Cornell University for one cropping season at **400,000** pesos? Si → **STOP and skip to Question 3** No → **Continue with Question 2**
2. Would you be willing to rent a quarter of a hectare of your land to the researchers from Cornell University for one cropping season at **600,000** pesos Si → **Continue with Question 3.** No → **END OF SURVEY**

3. At the chosen price, how many acres of your land would you be willing to rent to the researchers from Cornell? (they only require ¼ of a hectare but they can always rent more land if its available)?
______ hectáreas

B. Appendix 2: Choice Experiment

1. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	270 cargas/ha
Labor Requirements	Same amount of labor	Less labor
Costs	375,000 pesos	450,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**High Probability of Developing an Illness**
I select:		

2. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	300 cargas/ha
Labor Requirements	Same amount of labor	More labor
Costs	375,000 pesos	375,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**High Probability of Developing an Illness**
I select:		

3. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	240 cargas/ha
Labor Requirements	Same amount of labor	Same amount of labor
Costs	375,000 pesos	350,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**High Probability of Developing an Illness**
I select:		

4. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	300 cargas/ha
Labor Requirements	Same amount of labor	Same amount of labor
Costs	375,000 pesos	375,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**Low Probability of Developing an Illness**
I select:		

5. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	240 cargas/ha
Labor Requirements	Same amount of labor	More labor
Costs	375,000 pesos	375,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**High Probability of Developing an Illness**
I select:		

6. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	240 cargas/ha
Labor Requirements	Same amount of labor	More labor
Costs	375,000 pesos	450,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**Low Probability of Developing an Illness**
I select:		

7. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	300 cargas/ha
Labor Requirements	Same amount of labor	Less labor
Costs	375,000 pesos	450,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**High Probability of Developing an Illness**
I select:		

8. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	270 cargas/ha
Labor Requirements	Same amount of labor	Less labor
Costs	375,000 pesos	375,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**Low Probability of Developing an Illness**
I select:		

9. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	240 cargas/ha
Labor Requirements	Same amount of labor	Less labor
Costs	375,000 pesos	350,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**Low Probability of Developing an Illness**
I select:		

10. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	270 cargas/ha
Labor Requirements	Same amount of labor	More labor
Costs	375,000 pesos	450,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**Low Probability of Developing an Illness**
I select:		

11. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	240 cargas/ha
Labor Requirements	Same amount of labor	Same amount of labor
Costs	375,000 pesos	450,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**Low Probability of Developing an Illness**
I select:		

12. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	270 cargas/ha
Labor Requirements	Same amount of labor	Same amount of labor
Costs	375,000 pesos	375,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**Low Probability of Developing an Illness**
I select:		

13. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas /ha	270 cargas/ha
Labor Requirements	Same amount of labor	More labor
Costs	375,000 pesos	350,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**High Probability of Developing an Illness**
I select:		

14. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	300 cargas/ha
Labor Requirements	Same amount of labor	Less labor
Costs	375,000 pesos	350,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**Low Probability of Developing an Illness**
I select:		

15. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	270 cargas/ha
Labor Requirements	Same amount of labor	Same amount of labor
Costs	375,000 pesos	350,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**High Probability of Developing an Illness**
I select:		

16. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	300 cargas/ha
Labor Requirements	Same amount of labor	Same amount of labor
Costs	375,000 pesos	450,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**High Probability of Developing an Illness**
I select:		

17. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	300 cargas/ha
Labor Requirements	Same amount of labor	More labor
Costs	375,000 pesos	350,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**Low Probability of Developing an Illness**
I select:		

18. DO YOU WANT TO SWITCH?

	Technology A (Status quo)	Technology B (Alternative)
Average Yield	270 cargas/ha	240 cargas/ha
Labor Requirements	Same amount of labor	Less labor
Costs	375,000 pesos	375,000 pesos
Health/Environment	**High Probability of Developing an Illness**	**High Probability of Developing an Illness**
I select:		

C. Appendix 3: Risk Game

Serie 1

	Plan A	Plan B
1	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	15,600 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
2	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	17,205 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
3	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	19,041 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
4	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	21,335 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
5	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	24,317 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
6	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	28,676 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
7	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	34,411 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
8	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	42,411 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
9	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	50,470 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
10	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	68,823 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
11	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	91,764 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
12	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	137,647 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B

13	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	229,411 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

	Plan A	Plan B
14	9,176 for balls 1,2,3 2,294 for balls 4,5,6,7,8,9,10	390,000 for ball 1 1,147 for balls 2,3,4,5,6,7,8,9,10

Serie 2

	Plan A	Plan B
15	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	12,388 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
16	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	12,847 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
17	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	13,305 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
18	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	13,764 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
19	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	14,223 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
20	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	14,911 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
21	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	15,600 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
22	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	16,517 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
23	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	17,664 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
24	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	19,041 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
25	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	20,647 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
26	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	22,941 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
27	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	25,235 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

	Plan A	Plan B
28	9,176 for balls 1,2,3,4,5,6,7,8,9 6,682 for balls 10	29,823 for balls 1,2,3,4,5,6,7 1,147 for balls 8,9,10

Serie 3

	Plan A	Plan B
29	5,735 for balls 1,2,3,4,5 -917 for balls 6,7,8,9,10	6,882 for balls 1,2,3,4,5 -4,817 for balls 6,7,8,9,10

	Plan A	Plan B
30	917 for balls 1,2,3,4,5 -917 for balls 6,7,8,9,10	6,882 for balls 1,2,3,4,5 -4,817 for balls 6,7,8,9,10

	Plan A	Plan B
31	229 for balls 1,2,3,4,5 -917 for balls 6,7,8,9,10	6,882 for balls 1,2,3,4,5 -4,817 for balls 6,7,8,9,10

	Plan A	Plan B
32	229 for balls 1,2,3,4,5 -1,835 for balls 6,7,8,9,10	6,882 for balls 1,2,3,4,5 -3,670 for balls 6,7,8,9,10

	Plan A	Plan B
33	229 for balls 1,2,3,4,5 -1,835 for balls 6,7,8,9,10	6,882 for balls 1,2,3,4,5 -3,670 for balls 6,7,8,9,10

	Plan A	Plan B
34	229 for balls 1,2,3,4,5 -1,835 for balls 6,7,8,9,10	6,882 for balls 1,2,3,4,5 -3,211 for balls 6,7,8,9,10

	Plan A	Plan B
35	229 for balls 1,2,3, 4,5 -1,835 for balls 6,7,8,9,10	6,882 for balls 1,2,3,4,5 -2,523 for balls 6,7,8,9,10

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